Total Maximum Daily Load (TMDL)
Ashley River, South Carolina

Hydrologic Unit
03050202-020
03050202-040

South Carolina Water Quality Monitoring Stations
CSTL-102
MD-049

Pollutants of Concern: Oxygen Demanding Substances
(Carbonaceous and Nitrogenous Biochemical Oxygen Demand)

South Carolina Department of
Health and Environmental Control
Bureau of Water

September 30, 2003

Wade M. Cantrell
Larry E. Turner

D H E C
PROMOTE PROTECT PROSPER
South Carolina Department of Health
and Environmental Control

INDEX
State of South Carolina Administrative Record
TMDL Submittal for the Ashley River
Oxygen Demanding Substances

APPENDICES

A. Tenth Rule Justification Document
B. Model Calibration Report
C. TMDL Model Report
D. EPA Review of Modeling Approach
E. Responsiveness Summary to Public Comments on the Initial Draft Ashley River TMDL
F. BCDCOG Allocation
G. Public Notice for Revised TMDL
H. Responsiveness Summary to Public Comments on the Revised Draft TMDL

EXECUTIVE SUMMARY

The Charleston Harbor Estuary is located centrally on the South Carolina coast. It is composed of Charleston Harbor and its tributaries: the Ashley River, the Cooper River and the Wando River. The system is tidally influenced throughout. On December 31, 2002, U. S. Environmental Protection Agency Region 4 (EPA) approved a total maximum daily load (TMDL) for the Harbor, Cooper River and Wando River portion of the system. This report documents TMDL development for the Ashley River portion of the system.

Section 303(d) of the Clean Water Act and the EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require the states to establish TMDLs for all waterbodies. Priority is given to development of TMDLs for waterbodies identified under Section 303(d)(1)(A) and (B) as not meeting applicable water quality standards. For the purpose of information, TMDLs are to be established for those waterbodies not identified as impaired. Available information indicates the upper Ashley River does not meet the applicable water quality standard for dissolved oxygen (DO) for significant periods of time due to natural conditions. Two stations on the Ashley River (CSTL-102, Ashley River @ SC 165 and MD-049, Ashley River @ Magnolia Gardens) are considered impaired under criteria of Section 303(d) of the Clean Water Act and are listed on the S.C. 303(d) List for 2002. As such, the South Carolina Department of Health and Environmental Control (DHEC) is required to develop a TMDL for oxygen demanding substances for the Ashley River. These violations are considered due to natural conditions exacerbated by point and non-point sources of pollution; therefore, Section 48-1-83 (Pollution Control Act) and Section D.4.a. of R.61-68 (Water Classifications and Standards) apply. These provisions allow a lowering of DO of no more than 0.10 mg/L (the Tenth Rule).

A water quality model was developed to predict the impact of point source discharges on DO concentrations in the system. The model incorporated appropriate critical conditions, instream processes, and decay rates. Results indicate the need for an overall reduction in discharge of ultimate oxygen demand (UOD) to the Ashley River from the currently permitted level of 2791 lbs/day to 1781 lbs/day (36 percent reduction) at currently permitted plant flows to comply with the Tenth Rule. Allowable loading is 1903 lbs/day (32 percent reduction) when Dorchester County wastewater treatment facility (WWTF) expands from 4 to 8 MGD. The difference results from slightly higher dilution and flushing when additional water is added to the system. Concentration limits are required to ensure the water quality standard is met regardless of actual plant flows, which may be below permitted levels.

PROJECT SETTING

Charleston Harbor encompasses an area of 65 sq. miles, 40 sq. miles of which are marsh and lowlands. It is formed at the confluence of the Ashley, Cooper, and Wando Rivers, which drain an approximately 1,200 square mile region, and exchanges directly with the Atlantic Ocean (See Figure 1). Historically, the Ashley, Wando, and Cooper Rivers were all tidal sloughs with limited freshwater inflow and extensive tidal marshes. The Ashley River (approximately 30

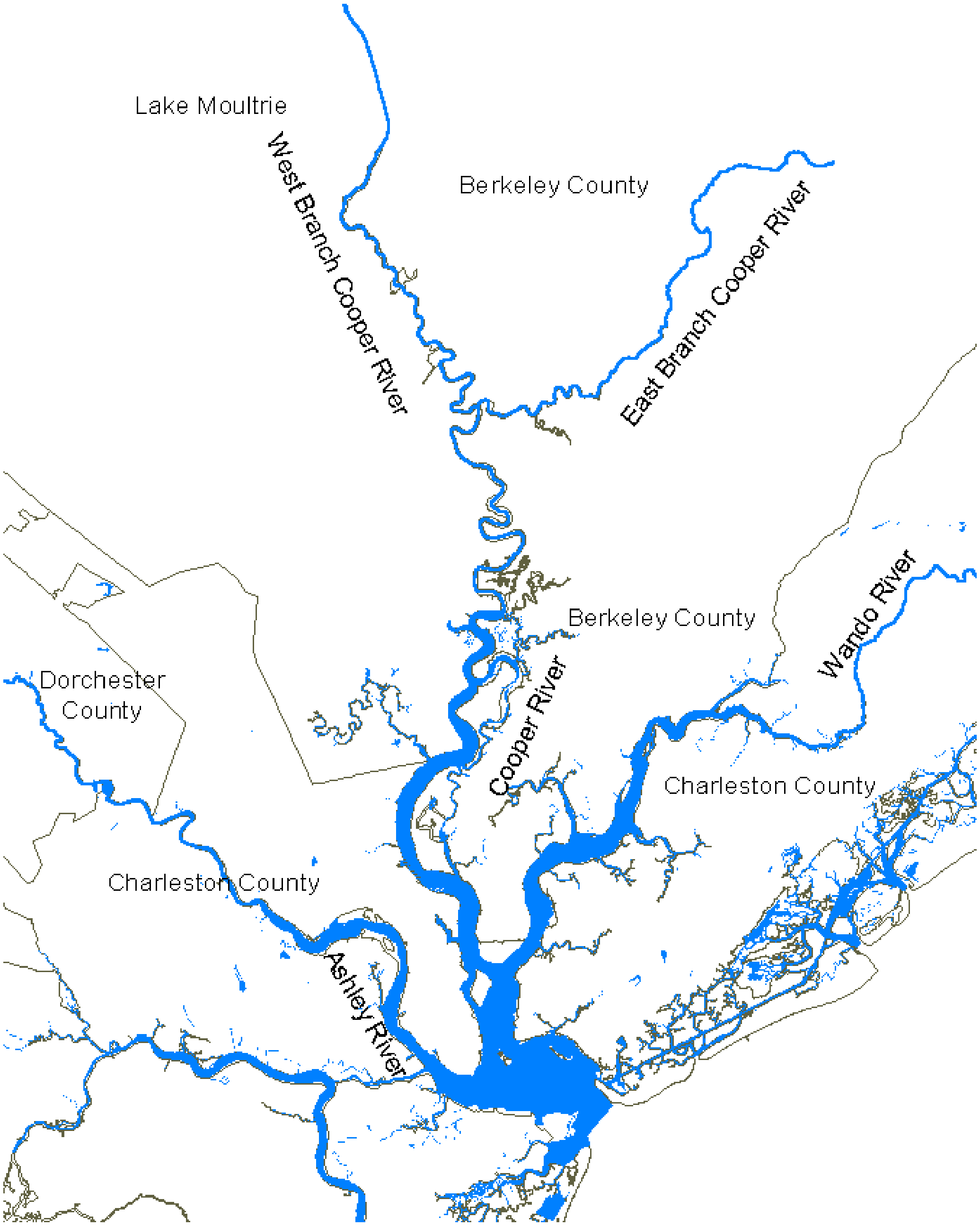


Figure 1. Site Location Map

miles in length) and the Wando River (approximately 20 miles in length) remain tidal sloughs with varying levels of urban development along their reaches. Via diversion of water from the Santee River basin, the Cooper River now carries significant freshwater and flows 48 miles from the tailrace of Pinopolis Dam to the Customs House Wharf. A TMDL for the Harbor/Cooper/Wando portion of the system was approved December 31, 2002. The Ashley River from Bacon Bridge to U.S. Highway 17, which under low flow conditions contributes little to no freshwater input to the system, is covered by the TMDL documented in this report.

BASIS FOR ESTABLISHING TMDL

Introduction

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40CFR Part 130) require states to develop TMDLs to restore and protect state waters. TMDLs are required for all waters; however, priority is given to those waters identified under section 303(d)(1)(A) as not meeting applicable water quality standards and, therefore, considered impaired. For those waters not identified as impaired, TMDLs for the specific purpose of developing information are required but only as State resources allow (40 CFR 130.7(e)). The TMDL process establishes the allowable loading of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and instream water quality conditions, so that the states can establish water quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991). Two DHEC ambient water quality monitoring stations in the Ashley River (CSTL-102, Ashley River @ SC 165 and MD-049, Ashley River @ Magnolia Gardens), which are sampled once a month, are considered impaired for dissolved oxygen under the criteria of Sections 303(d) and 305(b) of the Clean Water Act. A TMDL addressing the pollutants of concern (oxygen demanding substances) is required. Additionally, continuous ambient water quality data collected by the U. S. Geologic Survey (USGS) at three stations in the Ashley River as part of the Charleston Harbor Project (02172081, 021720869 and 02172090) show the Ashley River will not meet applicable criteria under the critical conditions deemed appropriate for determining wasteload allocations to be included in NPDES permits for dischargers to the river.

Problem Definition

Charleston Harbor and its tributaries are a complex estuarine system encompassing ecosystems ranging from salt to fresh open water habitats to inter-tidal saltwater and freshwater marshes and freshwater swamps. The Ashley and Wando Rivers are essentially tidal sloughs that carry limited fresh water from their relatively small drainage basins. The Cooper River is the only tributary to the harbor that carries significant freshwater, this coming from the diversion of water from the Santee River basin to the Cooper River via the diversion canal between Lakes Marion and Moultrie and the tailrace canal which connects Lake Moultrie to the West Branch of the Cooper River.

Inter-tidal estuarine systems are characterized by highly variable salinity and dissolved oxygen concentrations. Available information on these systems shows that dissolved oxygen concentrations frequently fall below the criteria established for such waters. These excursions are found during high temperature periods whether or not there are anthropogenic sources of oxygen demand to the system. Section 48-1-83(A) of Title 48, Chapter 1 (Pollution Control Act) states:

> "The department shall not allow a depression in dissolved oxygen concentration greater than 0.10 mg/l in a naturally low dissolved oxygen waterbody unless the requirements of this section are all satisfied by demonstrating that resident aquatic species shall not be adversely affected. The provisions of this section apply in addition to any standards for dissolved oxygen depression in a naturally low dissolved oxygen waterbody promulgated by the department by regulation."

The Antidegradation Rules of South Carolina's water quality standards (R.61-68.D.4) further recognize that natural conditions may cause a depression of dissolved oxygen in surface waters below the numeric standard while existing and classified uses are still maintained. This section states:

> "4. Certain natural conditions may cause a depression of dissolved oxygen in surface waters while existing and classified uses are still maintained. The Department shall allow a dissolved oxygen depression in these naturally low dissolved oxygen waterbodies as prescribed below pursuant to the Act, Section 48-1-83, et seq., 1976 Code of Laws:
>
>> a. Under these conditions the quality of the surface waters shall not be cumulatively lowered more than 0.1 mg/l for dissolved oxygen from point sources and other activities, or
>>
>> b. Where natural conditions alone create dissolved oxygen concentrations less than 110 percent of the applicable water quality standard established for that waterbody, the minimum acceptable concentration is 90 percent of the natural condition. Under these circumstances, an anthropogenic dissolved oxygen depression greater than 0.1 mg/l shall not be allowed unless it is demonstrated that resident aquatic species shall not be adversely affected. The Department may modify permit conditions to require appropriate instream biological monitoring."

Section 4(a) is referred to as the "Tenth Rule" while section 4(b) is referred to as the "10% Rule". During the early stages of the Charleston Harbor modeling project, the Department observed, based on continuous monitoring conducted by the USGS, that much of the Charleston Harbor system did not meet applicable water quality standards for dissolved oxygen during critical, high temperature conditions. The analysis described in Appendix A concluded that the low dissolved oxygen concentrations were a natural phenomenon that was further impacted by point source discharges and that the standard would not be attained regardless of point source discharges. The Department, with concurrence from a modeling workgroup composed of representatives of EPA, USGS, the University of South Carolina (USC), the S.C. Coastal

Conservation League, and Applied Technology and Management (ATM, consultants for the Cooper River Water Users Association), determined that the Tenth Rule should apply to the Charleston Harbor system, including the Ashley River.

Ashley River stations CSTL-102, Ashley River @ SC 165 and MD-049, Ashley River @ Magnolia Gardens are included on the Department's 303(d) list for 2002.

Waterbodies Impacted

Watershed Number	Waterbody	County
03050202-020	Ashley River	Dorchester
03050202-040	Ashley River	Charleston

Water Quality Parameter Not Complying With Criteria

The pollutants of concern are oxygen-demanding substances, carbonaceous and nitrogenous biochemical oxygen demand, and their impact on in-stream dissolved oxygen concentrations. Information from two DHEC ambient water quality monitoring stations in the Ashley River (CSTL-102, Ashley River @ SC 165 and MD-049, Ashley River @ Magnolia Gardens) indicates that this portion of the river is impaired for dissolved oxygen based on 303(d) listing criteria. Further, three USGS monitoring stations active during data collection for the Charleston Harbor Project (1992-1995, stations 02172081, 021720869 and 02172090) showed low dissolved oxygen concentrations during critical summer periods. In 2001, station 02172081 (Rd 165 at Cooke Crossroads) was reactivated and three additional stations were installed: 02172080 (US 17A), 021720812 (below Cooke Crossroads), and 02172084 (Bakers Landing). Limited data collected during the summer of 2001 at these stations are consistent with the previous data and show significant low DO periods during the hot weather periods.

Waterbody Classifications and Dissolved Oxygen (DO) Criteria

The Ashley River is classified in R.61-69 (Classified Waters) as shown below in Table 1. Note that in the TMDL document, the upper boundary of the model at Bacon Bridge (S.C. Hwy. 165) is referred to as mile 0. The locations where the different criteria apply are indicated as miles downstream of Bacon Bridge. Associated DO criteria, as defined in R.61-68 (Water Classifications and Standards), are also provided.

Table 1. Ashley River Classification and DO Standard

Segment	Approximate Miles Below Bacon Bridge	Classification	DO Standard
Above Bacon Bridge	<0	FW	Daily average of 5.0 mg/L with a low of 4.0 mg/L
Bacon Bridge to Church Creek	0 – 17.5	SA	Daily average of 5.0 mg/L with a low of 4.0 mg/L
Church Creek to Orangegrove Creek	17.5 – 24.4	SA*[1]	Site-specific, not less than 4.0 mg/L
Orangegrove Creek to Charleston Harbor	24.4 – 28.3	SA	Daily average of 5.0 mg/L with a low of 4.0 mg/L

[1]SA* indicates site-specific standard as indicated in R.61-69.

Freshwaters are:

> "Suitable for primary and secondary contact recreation, and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora. Suitable also for industrial and agricultural uses." (R.61-68)

SA waters are:

> "Tidal saltwaters suitable for primary and secondary contact recreation, crabbing and fishing except for harvesting of clams, mussels, or oysters for market purposes or human consumption and uses listed in Class SB. Also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora." (R.61-68)

TMDL TECHNICAL BASIS

Target Identification

Modeling indicates the controlling dissolved oxygen sag due to point sources occurs in the Bacon Bridge to Church Creek segment. A plot of the longitudinal impact associated with the point sources appears in the TMDL model report included as Appendix C (see Figure 5 in Attachment B to the TMDL model report). As indicated in Table 1, this segment is classified SA, which carries a dissolved oxygen standard of 5 mg/L as a daily average with a minimum of 4 mg/L. As discussed above and in Appendix A, the Ashley River is considered to be water quality limited for oxygen demanding substances due to naturally occurring, low dissolved oxygen concentrations that fail to meet these numeric criteria. Therefore, the water quality target for this TMDL is a dissolved oxygen depression of no more than 0.10 mg/L, as a daily average, as authorized by Regulation 61-68, Section D.4 and the S.C. Pollution Control Act, Section 48-1-83.

It is recognized that there are both point and non-point sources of oxygen demanding substances in the Ashley River watershed. The non-point sources include both runoff from developed areas and naturally occurring material from headwater swamps and bordering marshes. The critical conditions on which the wasteload allocations are based represent hot, dry periods during late summer. Freshwater inflow is limited to a nominal headwater flow of 5 cfs, which is considered to approach 7Q10, and WWTF effluent flow. Runoff would be absent during these periods, so direct inputs of anthropogenic non-point source BOD from land surfaces to the water column should be zero. Dissolved material introduced during runoff events should be flushed from the system along with the stormwater, which would prevent this material from impacting river DO levels during subsequent dry periods. Suspended material would tend to be transported downriver during high flow, but might also settle in some areas. Any impact from previous wet periods, as might result from benthic deposition and accumulation, is taken into account by the sediment oxygen demand (SOD), as well as benthic source terms for CBOD and NBOD that were determined during model calibration. Likewise, background, or natural, non-point sources should also be accounted for by the kinetic terms, as well as the inputs of CBOD and NBOD at the model boundaries. Since anthropogenic and background non-point sources are either absent during dry weather or incorporated through processes that are already included, non-point source pollution is not a concern in this analysis.

This TMDL focuses on compliance of point sources with the Tenth Rule. EPA has reviewed the modeling approach and concurred that, given the current modeling for this system and the identified target for this analysis, a dry weather, critical condition TMDL, including only point sources, is appropriate. Non-point sources of pollution may be considered in any future modeling work for this system while the Department continues its efforts to address non-point sources through existing programs.

Predictive modeling indicates reducing the discharge of biochemical oxygen demand (BOD), both carbonaceous (CBOD) and nitrogenous (NBOD), by the domestic wastewater treatment facilities on the upper Ashley River will achieve the water quality target. The carbonaceous component is represented in the model as ultimate CBOD (CBODu). Five-day CBOD (CBOD5) is related to CBODu by the F-Ratio (a dimensionless factor characteristic of the source and treatment level of the wastewater). The nitrogenous component is represented in the model as ammonia nitrogen (NH3-N). Ultimate oxygen demand (UOD), CBOD5, and NH3-N are related according to the following equation:

$$UOD = 8.34*Flow*(F\text{-}Ratio*CBOD5 + 4.57*NH3\text{-}N),$$

where

UOD = ultimate oxygen demand (lbs/day),

8.34	=	units conversion factor,
F-Ratio	=	CBODu/CBOD5, assumed = 1.5 (unitless),
CBOD5	=	five-day carbonaceous biochemical oxygen demand (mg/L),
Flow	=	effluent flow (MGD),
4.57	=	units of oxygen consumed per unit of NH3-N oxidized (unitless),
NH3-N	=	ammonia nitrogen (mg N/L).

Ashley River TMDL modeling indicates allowable UOD depends on the effluent mix of CBOD5 and NH3-N. Modeling also indicates allowable mass loadings depend on effluent flow. For these reasons, this TMDL and resulting recommended permit limits will be in terms of CBOD5 (or BOD5) and NH3-N mass loadings and concentrations. UOD loads are included for information only.

The approach used to apply the target in the recently approved Cooper River, Wando River, Charleston Harbor TMDL was based on dividing the system into segments with similar chemical and physical characteristics and calculating a volume-weighted daily average dissolved oxygen depression for each segment (Greenfield, 2002). The critical segments were the lower Cooper River from Goose Creek to the mouth (river mile 6.3 to 13.7) and the Cooper/Wando estuary (river mile 4.2 to 6.3). A similar approach is used for the Ashley River TMDL, as described in Appendix C. Two critical segments were identified: mile 2 to mile 7 and mile 7 to mile 12 (Bacon Bridge is defined as mile 0). The upper segment is referred to as "Segment 1" and the lower segment as "Segment 2". The depression in dissolved oxygen was determined as the difference between two model runs: a no-load run with point sources turned off (zero flow, zero load) and a load run with the point sources turned on. The difference between the runs represents the impact of the discharges and is referred to as the "delta DO." The target is a maximum daily average delta DO of 0.10 mg/L in each segment determined as a volume-weighted average.

Point Sources

The initial draft Ashley River TMDL proposed in December 2000 included six NPDES permitted discharges to the Ashley River. Carolina Water Service (CWS) Teal on the Ashley WWTF (NPDES Permit No. SC0030350) is located upstream of the model boundary and was evaluated using a separate analysis which determined a wasteload allocation of 3.4 lbs/day UOD (Sullins, 2000). Charleston CPW Pierpont WWTF (SC0026069) was inactivated in 2001. The four discharges included in this TMDL and their existing permit limits are shown in Table 2. Carter's Texaco (SC0044521) and GS Roofing Products (SC0002771) are in the model domain, but are not significant sources of oxygen demanding substances. The locations of the point sources in Table 2 are shown in Figure 2. CWS Teal on the Ashley WWTF is also shown, although it is located upstream of Bacon Bridge and out of the BRANCH/BLTM model domain.

Table 2. Existing Monthly Average NPDES Permit Limits

Location	WWTF	NPDES Permit No.	Flow	CBOD5 or BOD5[1]		NH3-N[2]		UOD[3]
			MGD	mg/L	lbs/day	mg/L	lbs/day	lbs/day
Segment 1	CPW Summerville	SC0037541	10	12.5	1042	2	166.8	1601
	CWS King's Grant	SC0021911	0.238	30	59.5	20	39.7	271
Segment 2	Lower Dorchester	SC0038822	4	15	500	1	33.3	903
	Middleton Inn	SC0039063	0.014	30	3.5	20	2.3	15.9

[1]Summerville is CBOD5; others are BOD5.
[2]Assumed 20 mg/L for CWS King's Grant and Middleton Inn.
[3]Summerville has UOD limit of 1601 lbs/day; others calculated.

Non-Point Sources

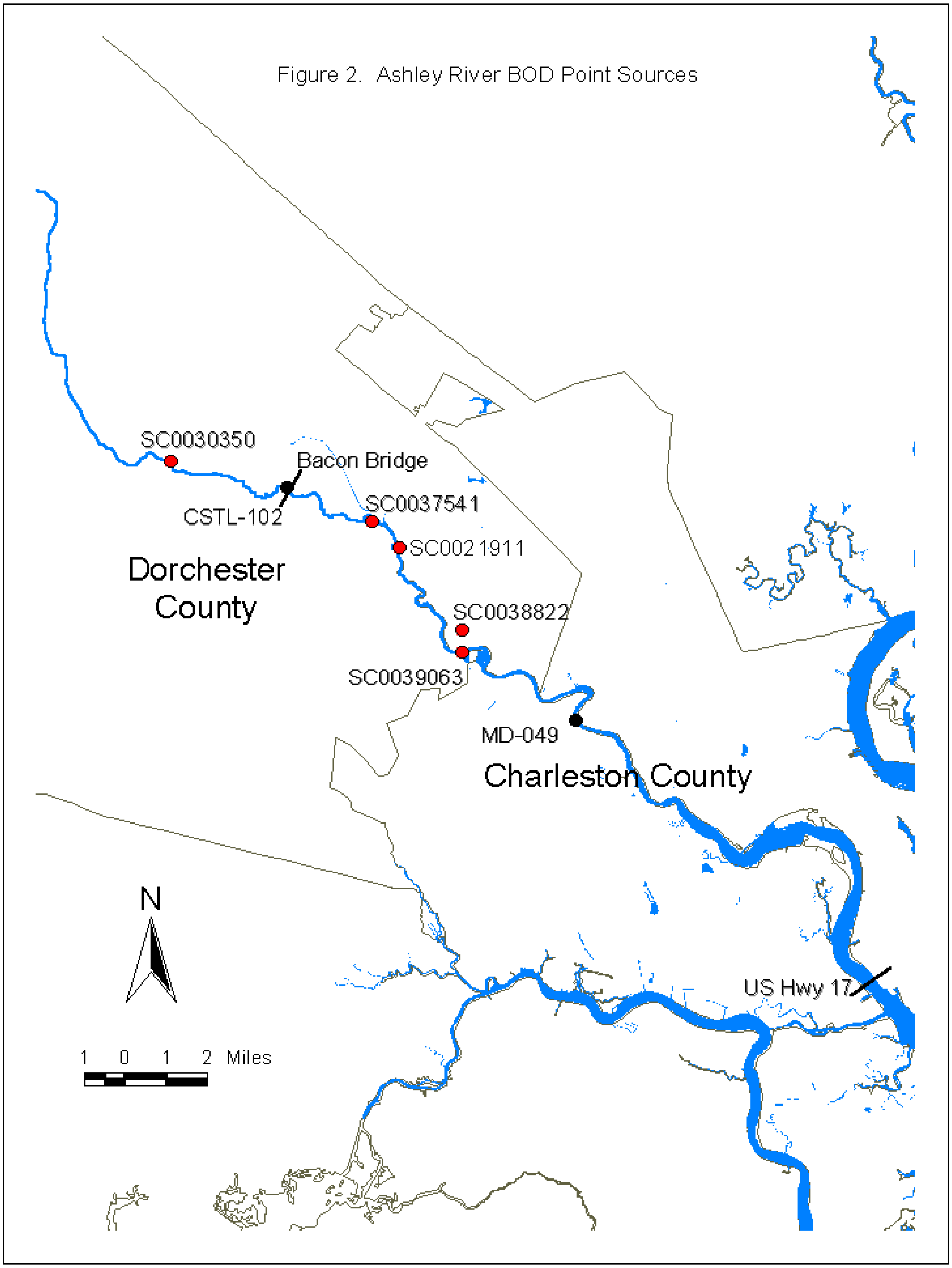
As discussed above, this is a dry-weather, critical condition TMDL. Non-point sources are considered in this analysis only as they impact boundary and background conditions in the modeling.

MODEL DEVELOPMENT

History of Model Development

In the early 1990's, the South Carolina Coastal Council (now DHEC's Office of Ocean and Coastal Resource Management) initiated the Charleston Harbor Project (CHP), an

Figure 2. Ashley River BOD Point Sources



interdisciplinary, comprehensive study of the Charleston Harbor System (CHS). A Charleston Harbor Modeling Group was formed to develop a monitoring and modeling plan for the CHS. One objective of the CHP was to develop a state-of-the-art water quality model to be provided to DHEC for TMDL development. Another objective was development of a non-point source (NPS) water quality model. The NPS effort was completed for only a small urban watershed and did not provide the information needed to conduct dynamic, non-point source loading simulations. The CHP model workgroup included representatives from DHEC, SC Coastal Council, EPA (Region 4 and Office of Research and Development), USGS, Clemson University, and the University of South Carolina, among others.

The CHP model workgroup implemented a plan to develop separate one-dimensional (1-D) water quality models for the rivers and tie them to a three-dimensional (3-D) model of the harbor. Each of the river models was to have an overlapping segment with the harbor model so there would be continuity between the models. After initial data collection and several years of effort to set up a usable 3-D model, the project failed to produce results. Due to technical problems (the hydrodynamic and water quality models were never successfully linked) and model constraints, it was decided to proceed with a two-dimensional (2-D) model for the harbor rather than the 3-D model originally proposed. Also, it was decided to use the Branch-Network Flow Model/Branched Lagrangian Transport Model (BRANCH/BLTM) modeling platform, rather than Water Quality Analysis Simulation Program (WASP), for the rivers. Ultimately, plans to model the harbor were dropped and the Cooper River BRANCH/BLTM model was extended to the Customs House and joined with the Wando River model. The major reasons why the CHP was not successful in developing a 3-D model of the Harbor were the models were too complex for the computers available at the time, the research was not successful in getting the selected hydrodynamic model to communicate with the water quality model, and the collection of physical and chemical data of the CHS was limited. Work by USGS, in conjunction with DHEC, continued on the less complicated 1-D BRANCH/BLTM models of the Cooper/Wando system and the Ashley River.

In the late 1990's, the Charleston Commissioners of Public Works (CPW) proposed a major new discharge for the Cooper River. After discussions with DHEC, CPW was concerned the Charleston Harbor Project model for the Cooper River would not be completed within their review time frame and that the BRANCH/BLTM model, which ended just downstream of the proposed discharge location, would not be adequate to evaluate their proposal. CPW proposed to hire a private consulting group, Applied Technology and Management (ATM), to develop a 3-D model for the entire system (similar to the original Charleston Harbor Project proposal) and provide this model to DHEC for TMDL development. This CPW effort, including collection of additional velocity, flow, and DO data, eventually came to be supported by the major discharges to the Cooper River. Ultimately, ATM developed a calibrated 2-D model of the Cooper River, Wando River, and Charleston Harbor, which was used to develop an approved TMDL. The model was not completed on the Ashley River side.

The BRANCH/BLTM model of the Ashley River was completed in 1998 and is reported in the USGS Water-Resources Investigations Report 98-4150 (Conrads, 1998). Using the USGS model, DHEC developed a draft TMDL for the Ashley River in December 2000.

Initial Draft Ashley River TMDL

The initial draft Ashley River TMDL developed in December 2000 concluded that reductions of 66 to 69 percent from permitted UOD loading to the upper Ashley River was necessary to meet the requirements of the Tenth Rule (Sullins, 2000).

Public Comment

The initial draft Ashley River TMDL was placed on public notice on December 15, 2000. At the request of stakeholders, DHEC extended the deadline for comments from January 15 to January 31, 2001. At that time, DHEC received significant public comment on the proposed TMDL. The comments included concerns about technical aspects of both the calibrated model developed by USGS and the critical conditions model developed by DHEC. In response to these concerns, USGS, EPA, and DHEC conducted a complete review of both models. During the review period, additional fieldwork was conducted by ATM to obtain measured nitrification rates throughout the CHS. This information was used to update the model. A responsiveness summary addressing all comments received on the initial draft Ashley River TMDL appears in Appendix E.

Model Calibration Review

The original Ashley River BRANCH/BLTM model was calibrated and validated to 1992 and 1993 datasets collected as part of the CHP as described by Conrads (1998). USGS, EPA, and DHEC reviewed the original model in response to the comments received on the draft TMDL. This review resulted in revisions to both the BRANCH flow model and the BLTM water quality model, both to address specific comments and to improve model performance. Revisions included routing the effluent flows in BRANCH and adjusting the rate coefficients in BLTM.

Previously, the flow model did not include the water from the discharges, which were input as mass loadings only. This approach is common practice in many models when the size of the receiving waterbody is large compared to the volume of effluent. During the review, it was determined that the effluent flow can be a significant fraction of the total net flow in the upper Ashley River under low-flow conditions. Therefore, the revised approach is preferable.

Public comments expressed concern about several of the kinetic rate coefficients used in the water quality model. As noted above, additional fieldwork provided measured nitrification rates throughout the CHS. In response to the comments and the availability of new information on the nitrification rate, the water quality model was re-calibrated.

Modifications and results for the re-calibrated model are described in detail by Conrads (2003), which is included as Appendix B. The revised model was provided to DHEC for development of the critical conditions model used for the TMDL. All of the kinetic inputs used in the critical conditions model are the same as those determined in the revised calibration.

Critical Conditions Model Review

The critical conditions model used to develop the December 2000 initial draft Ashley River TMDL is described in Sullins (2000). Comments related to the critical conditions model used to develop the initial draft TMDL were considered during the development of a new critical conditions model. The starting point for the new critical conditions was the updated calibration model. The development process is summarized below. A separate report describing the critical conditions model in detail was prepared in advance of this TMDL and provided to EPA to allow for EPA review of the modeling approach. The TMDL model report is included as Appendix C.

Critical Flow Period. The critical flow period was chosen in accordance with the recommendations of Butcher (1998). The recommended critical flow period includes setting uncontrolled freshwater inflows to 7Q10 flows and selecting the seaward tidal boundary to represent a full lunar month including both spring and neap tides.

Actual 7Q10 freshwater flow in the Ashley River is unknown. Available data suggest little freshwater inflow occurs under 7Q10 conditions. In the model, the headwater boundary was set to a net inflow of 5 cfs. This flow is considered to approximate 7Q10 conditions.

The previous TMDL model used measured water levels from November 1-December 30, 1993 at the seaward boundary. The seaward boundary data were retained in the current TMDL model. The period includes both spring and neap tides as recommended by Butcher (1998). Criticality was assessed by comparing this period to 14 additional periods for which data were available. This period was found to be intermediate in terms of predicted dissolved oxygen impact in the critical river segments. Predicted impact was 14 percent higher during the most critical period and 13 percent lower during the least critical period when compared to the period used in the TMDL model.

Point Source Inputs. Point source flows were set to the monthly average permitted levels given above in Table 2. Point source loads were initially input at permitted levels and then adjusted until the water quality target was achieved. Both the calibration model and the TMDL model represent CPW Summerville and CWS King's Grant as a single point source input and Lower Dorchester and Middleton Inn as a second point source input. These model point sources are referred to as "Pipe 1" and "Pipe 2", respectively. Loads for several scenarios used to develop the TMDL are given in the TMDL model report included as Appendix C.

The Berkeley-Charleston-Dorchester Council of Governments (BCDCOG) is currently in the process of amending the tri-county plan to increase Dorchester County's flow from 4 to 8 MGD. Therefore, TMDL scenarios are developed for both the existing flow of 4 MGD and the expansion to 8 MGD.

Water Quality Boundary Conditions. Water quality boundary conditions were determined in accordance with the recommendations in Butcher (1998). Recommended boundary conditions include the 25th percentile dissolved oxygen concentration and 75th percentile temperature and concentration for other constituents determined from measured data during the summer months.

Available data for July and August during 1996-2001 were combined and 25th/75th percentiles were determined and used for boundary inputs to the TMDL model. The 1996-2001 period was chosen to represent conditions since the treatment plant upgrade and load reduction by the City of Summerville in 1995. At the time of model development, published data were available through 2001. Boundary values and data sources appear in the report in Appendix C.

Meteorological Conditions. Meteorological conditions drive the river temperature simulation in the Ashley River model. They also influence the algae simulation; however, in accordance with Butcher (1998), algal components were turned off in the TMDL model. Meteorological data at Charleston Airport were obtained from the Southeast Regional Climate Center. The 75th percentile daily minimum and maximum air temperatures during 1992-2001 for combined July and August data were 75 and 93 °F, respectively. The 25th percentile wind speed during July and August for 1999-2001 was 4.6 mph. These values were used as inputs to the TMDL model.

Water Quality Target. The initial draft Ashley River TMDL applied the allowable delta DO to point locations. As noted above, an alternative approach was developed by EPA for the Cooper River, Wando River, Charleston Harbor TMDL in which the delta DO is applied as a volume-weighted average over a river segment. The volume-weighted average approach is used here. The segments were defined above. The analysis used to determine the segments appears in the report in Appendix C.

EPA Review of Modeling Approach

The model calibration report (included as Appendix B) and the TMDL model report (included as Appendix C) were provided to EPA Region 4 modeling staff for review prior to the drafting of the TMDL. EPA modeling staff agreed with the modeling approach (EPA comments are included as Appendix E).

REVISED TOTAL MAXIMUM DAILY LOADS

Critical Conditions Loading

Revised loadings were determined using the critical conditions model. Model inputs for the critical conditions model are given above and in the TMDL model report in Appendix C. These conditions represent dry periods when freshwater inflow is limited to a nominal headwater flow, considered to approach 7Q10, and WWTF effluent flow. These conditions approach worst-case conditions for the impact of point sources on river DO levels. The wasteloads determined for these critical conditions are considered to be protective of the river DO standard when river flow is equal to or greater than 7Q10 since higher flows would provide greater dilution. Higher river flows are expected during wet weather, so the wasteloads should be protective under these conditions. Therefore, the wasteload allocations given below apply during wet weather conditions as well as during the dry weather design conditions represented in the modeling.

As discussed above and in detail in Appendix C, two critical river segments were identified:

Segment 1 (mile 2 to mile 7) including CPW Summerville WWTF and CWS King's Grant WWTF, and Segment 2 (mile 7 to mile 12) including Lower Dorchester WWTF and Middleton Inn WWTF. The segments were determined for the headwater boundary inflow of 5 cfs used for the TMDL model and may not be appropriate under different design flow conditions. Modeling indicated some interaction between the segments; however, under TMDL flow conditions, the predicted impact in Segment 1 is controlled by CPW Summerville WWTF and CWS King's Grant WWTF, and Segment 2 impact is controlled by Lower Dorchester WWTF and Middleton Inn WWTF.

In addition, modeling indicated that allowable loading depends on: effluent flow, effluent mix of CBOD and NH3-N, and effluent dissolved oxygen. Therefore, the TMDL is in terms of effluent flow (permitted flow) and specific concentration limits for CBOD5 or BOD5, NH3-N, and DO. Calculated UOD, CBOD5 or BOD5, and NH3-N mass loads are provided for information and for NPDES permitting purposes as may be appropriate. In the TMDL model, effluent dissolved oxygen was set to existing permit limits of 7 mg/L for Summerville CPW, 5 mg/L for Lower Dorchester, and 5 mg/L for CWS King's Grant. Middleton Inn was raised to 5 mg/L from 2 mg/L.

Several model scenarios were used in the development of the TMDL, as discussed in the report in Appendix C. Results were provided to the Berkeley, Charleston, Dorchester Council of Governments (BCDCOG). The BCDCOG determined allocations. The allocations are shown in Tables 3a (existing flows) and 3b (Dorchester County expansion to 8 MGD). Segment 2 delta DO is held below the standard of 0.10 mg/L because additional loading to Segment 2 impacts Segment 1. The BCDCOG allocation letters are included as Appendix G. Note the BCDCOG allocations included equal effluent DO concentrations for CPW Summerville WWTF and the allocation held in reserve.

Table 3a. TMDL Wasteload Allocations—Existing Plant Flows

Location	**WWTF**	**NPDES Permit No.**	**Flow**	**CBOD5 or BOD5[1]**		**NH3-N[2]**		**DO**	**UOD[4]**	**Delta DO**
			MGD	mg/L	lbs/day	mg/L	lbs/day	mg/L	lbs/day	mg/L
Segment 1	CPW Summerville	SC0037541	10	5.0	417.0	0.80	66.7	7.0	933	0.09
	Reserve[3]	--	0.238	5.0	9.9	0.80	1.6	7.0	22	0.01
Segment 2	Lower Dorchester	SC0038822	4	14.0	467.0	0.80	26.7	5.0	826	0.08
	Middleton Inn	SC0039063	0.014	14.0	1.63	0.80	0.09	5.0		

[1]Either lab test may be used to demonstrate compliance.
[2]Actual model input of 0.807 mg/L used to calculate UOD.
[3]Assimilative capacity currently not allocated but held in reserve per BCDCOG recommendation.
[4]UOD for information only; TMDL wasteload allocations are for CBOD5/BOD5 and NH3-N.

Table 3b. TMDL Wasteload Allocations—Dorchester County Expansion to 8 MGD

Location	**WWTF**	**NPDES Permit No.**	**Flow**	**CBOD5 or BOD5[1]**		**NH3-N[2]**		**DO**	**UOD[4]**	**Delta DO**
			MGD	mg/L	lbs/day	mg/L	lbs/day	mg/L	lbs/day	mg/L
Segment 1	CPW Summerville	SC0037541	10	5.0	417.0	0.80	66.7	7.0	933	0.09
	Reserve[3]	--	0.238	5.0	9.9	0.80	1.6	7.0	22	0.01
Segment 2	Lower Dorchester	SC0038822	8	7.0	467.0	0.80	53.4	5.0	948	0.08
	Middleton Inn	SC0039063	0.014	14.0	1.63	0.80	0.09	5.0		

[1]Either lab test may be used to demonstrate compliance.
[2]Actual model input of 0.807 mg/L used to calculate UOD.
[3]Assimilative capacity currently not allocated but held in reserve per BCDCOG recommendation.
[4]UOD for information only; TMDL wasteload allocations are for CBOD5/BOD5 and NH3-N.

Seasonality

The TMDL modeling is based on critical conditions for the impact of point sources on instream DO concentrations. These conditions include hot, dry weather, as may occur during the summer and early fall. Under these conditions, instream DO concentrations are at seasonal lows (often lower than the numeric standard of 5 mg/L), and reduced freshwater inflow limits the flushing of pollutants from the system. The TMDL developed for the Ashley River is a low flow, high temperature, critical-condition TMDL. The TMDL wasteload allocations given above should be protective of water quality at other times of the year.

Margin of Safety

TMDLs are required to include a margin-of-safety (MOS) to account for uncertainty in the technical evaluation. This margin-of-safety can be explicit, as when a percentage of the TMDL loading is reserved as a MOS and not allocated, or it can be implicit, as when conservative modeling assumptions are used to provide a MOS. For this TMDL, an implied MOS is utilized. This is achieved through use of conservative modeling assumptions, input of all point sources at permitted flows and loadings, evaluation at spring and neap tidal conditions, and inclusion of freshwater inflows approximating 7Q10 conditions. Note the reserve capacity indicated in this TMDL has been held for planning purposes unrelated to the MOS.

IMPACT ON ENDANGERED SPECIES

Ashley River watersheds 03050202-020 and 03050202-040 are contained within the borders of Berkeley, Charleston, and Dorchester Counties. Of the endangered species known to occur in these counties, the shortnose sturgeon, *Acipenser brevirostrum*, is the species likely to be most affected by any change in Ashley River dissolved oxygen concentrations.

Application of the Tenth Rule will allow a *de minimis* lowering of dissolved oxygen levels in the Ashley River. Under critical conditions, the TMDL will allow a lowering of dissolved oxygen of one tenth of one part per million (0.10 mg/L) below natural conditions. This will protect the aquatic life uses of all species, including the shortnose sturgeon, as related to dissolved oxygen.

IMPLEMENTATION PLAN

As a critical conditions TMDL dealing with point sources, the loadings identified above will be implemented through limits placed on NPDES permits.

This TMDL is developed to ensure point source compliance with the Tenth Rule provision of R.61-68. Non-point sources of pollution are not addressed in this TMDL. The Department will continue to address these sources of pollution through the NPDES stormwater permitting program, the 401 Water Quality Certification program, the State Stormwater Management & Sediment Reduction Act, the S.C. Non-point Source Management Plan, and other programs as available to control non-point source inputs to the watershed.

REFERENCES

Butcher, J.B., 1998. Review of South Carolina modeling applications for dissolved oxygen. Report prepared by Tetra Tech, Inc. for EPA. May 6, 1998. 13 pp.

Conrads, P.A., 2003. Enhancements to the BRANCH model and re-calibration of the BLTM model of the Ashley River. Report prepared for EPA Region 4. July 22, 2003. 27 pp.

Conrads, P.A., 1998. Simulation of temperature, nutrients, biochemical oxygen demand, and dissolved oxygen in the Ashley River near Charleston, South Carolina. USGS Water-Resources Investigations Report 98-4150. 56 pp.

Greenfield, J.M., 2002. Charleston Harbor TMDL model review, Ashley Cooper river system, final review package. May 2, 2002. 23 pp.

South Carolina Department of Health and Environmental Control, 2001. Water Classification and Standards (Regulation 61-68) Classified Waters (Regulation 61-69).

Sullins, N.R., 2000. draft Total Maximum Daily Load (TMDL), Ashley River, South Carolina. December 4, 2000.

United States Environmental Protection Agency. 1991. Guidance for Water Quality Based Decisions: The TMDL Process, Office of Water, EPA 440/4-91-001.

APPENDIX A

TENTH RULE JUSTIFICATION DOCUMENT

INTERNAL MEMORANDUM
SCDHEC, OCTOBER 2002

D H E C

PROMOTE PROTECT PROSPER

South Carolina Department of Health
and Environmental Control

MEMORANDUM

TO: File: Charleston Harbor System TMDL

FROM: Larry Turner, Manager
Water Quality Modeling Section

SUBJECT: Justification for Use of the 0.1 Rule for Determining Allowable Loadings of Oxygen Demanding Substances to the Charleston Harbor System

DATE: October 29, 2002

This memorandum is being written in response to comments, both written and oral, regarding the Department=s decision to apply the 0.1 Rule to develop a total maximum daily load for the Charleston Harbor system.

The State of South Carolina has adopted water quality standards (R.61-68) to protect water quality and water uses. Criteria, both numeric and narrative, have been adopted to ensure that uses are maintained. Narrative criteria describe a water quality goal that is to be attained while numeric criteria provide a numeric value that should not be exceeded or violated. For dissolved oxygen, a minimum value necessary to protect against both lethal and sub-lethal effects has been adopted and, for some waters, a daily average value has been established for additional protection.

R.61-68 has adopted certain critical flow conditions for application of numeric criteria for purposes of permit issuance, wasteload allocation, load allocation and mixing zone determinations. In tidal situations, the regulation requires that flows that approximate 7Q10 be used. The Department is required to issue wasteload allocations and permits that protect water quality for the conditions under which the standards are applicable, critical conditions of low flow and dilution and the conditions that could reasonably occur during such periods. Wasteload allocation analyses (models) are conducted based on these critical conditions.

R.61-68 acknowledges that certain naturally occurring conditions may cause a depression of dissolved oxygen in surface waters while existing and classified uses are still maintained. In these situations, Section D.4.a states the dissolved oxygen concentration shall not be cumulatively lowered more than 0.1 mg/l from point sources and other activities (0.1 Rule). Section D.4.b allows a depression greater than 0.1 mg/l only if it is demonstrated that resident aquatic species are not adversely affected (the A10% Rule@).

DHEC evaluates when the 0.1 Rule should apply on a case by case basis depending on the physical characteristics of the system, ambient water quality data and modeling. This approach was used successfully to apply the 0.1 Rule to develop a TMDL in the Waccamaw/ICWW system and to develop wasteload allocations for the Sampit River.

The Department looked at the three factors given above to determine if the 0.1 Rule should apply to the Charleston Harbor system as a whole. A qualitative evaluation of the physical characteristics of the system, data from DHEC=s ambient monitoring network and the USGS real time monitoring network established as part of the Charleston Harbor Project (CHP), and models developed as part of the CHP were used to determine if the 0.1 Rule should apply.

<u>Qualitative Analysis of System Characteristics</u>

A qualitative evaluation of the system was conducted. Based on experience with other tidal systems (Waccamaw River, Sampit River, Beaufort River) and information obtained by the SCDNR, it is known that tidal rivers with little freshwater inflow, such as the Ashley and Wando Rivers, experience depressed DO levels below the adopted numeric criteria. It is also known that in tidal rivers where freshwater inflow is relatively small compared to the tidal prism, DO can be depressed in the transition zone between tidal and non-tidal areas. Based on the characteristics of the system, it was determined that low dissolved oxygen concentrations were a natural phenomenon in the Charleston Harbor system.

<u>Water Quality Data Analysis</u>

Available water quality data for the system were reviewed. Ambient data collected by DHEC at several locations in the Cooper River showed only infrequent violations of the Aminimum of 4 mg/l@ standard. Data collected in the Ashley River showed sufficient violations (greater than 10%) of either the Aminimum of 4 mg/l@ or the Adaily average of 5 mg/l@ standard to be placed on the 303(d) list since at least 1996. The Ashley River was on the 1992 list; however, the parameter of concern was not specified.

As part of the Charleston Harbor Project, USGS operated a system of 15 continuous monitoring stations in the Ashley River (3), Wando River (4) and Cooper River (8) during the period October 1991 through September 1995. Not all stations were active for the entire period. Minimum, average and maximum dissolved oxygen levels were reported for those days when the stations were in operation and working properly. Table 1 summarizes compliance with applicable criteria for the months of June, July, August, September and October for each station with stations listed from upstream to downstream. These months were evaluated since stress due to naturally low dissolved oxygen concentrations are more likely to occur then. All of the stations have a requirement for a minimum of 4 mg/l DO while certain stations in the Wando and Upper Cooper Rivers have an additional requirement for a daily average of 5 mg/l. All daily values for each month for the period of record were evaluated. The number not meeting the standard was determined and the percentage of days violating for the month was calculated.

Monitoring results show that all stations in the Wando River violated both the minimum of 4 and daily average of 5 mg/L criteria greater than 25% of the days for which data were available for the months of July, August and September. In addition, two stations violated both criteria greater than 25% of the time in June and one station in October. All stations violated both criteria during August more than 49% of the time. For the Cooper River, results were more varied with one station (Cooper River at Customs House) showing no violations while one (Cooper River at Army Depot) violated the minimum requirement of 4 mg/L more than 75% of the days in June, July, August and September. With the exception of the Cooper River at the Customs House, all stations in the Ashley, Cooper and Wando Rivers and Charleston Harbor experienced violations of the dissolved oxygen standard at some time during the summers of 1992-1995. Violations were especially prevalent during the month of August with violations ranging from infrequent to almost continuous depending on the station.

Model Evaluation

The modeling effort for the Charleston Harbor system has been ongoing since the early 1990's. The initial effort, part of the Charleston Harbor Project (CHP), was to develop separate models for the Ashley and Cooper Rivers and link them to a model for the harbor. Due to linkage problems, the harbor model was dropped. Additionally, the decision was made for the US Geological Survey to use the BRANCH/BLTM modeling platform for the rivers rather than the WASP platform. The BRANCH/BLTM model for the Cooper was extended downstream to include the Wando River. The BRANCH/BLTM model was developed to the point where it could be used to evaluate load vs. no load situations. The model predicted that under critical conditions with the dischargers removed, the system would not meet the water quality criteria for dissolved oxygen.

While the BRANCH/BLTM model was under development, the Charleston Commissioners of Public Works proposed development of another model using the WQMAP system. The WQMAP model was to include the Charleston Harbor/Cooper River/Ashley River system. The CPW had plans for a new discharge to be located on Daniel Island near the lower boundary of the BRANCH/BLTM model. CPW officials proposed the new model because they feared the BRANCH/BLTM model would not be able to evaluate the new discharge. A workgroup including participants from DHEC, USGS, USC, EPA, ATM (developers of the WQMAP model) and the SC Coastal Conservation League concluded that the BRANCH model, which had relatively short run times, could be used as a screening tool to narrow options to be evaluated with the WQMAP model. ATM agreed with the conclusion to evaluate the system using the 0.1 Rule (see ATM APresentation to SCDHEC: Suggested Modifications to Surface Water Quality Classifications and Standards,@ December 12, 1996, portions attached). Not only did ATM agree with the application of the 0.1 Rule, they provided DHEC with a post-processor to allow extraction of data at selected points in the model to allow evaluation of model results based on the 0.1 Rule.

Conclusions

The system as a whole does not consistently meet numeric water quality criteria for dissolved oxygen for significant periods of time during the summer months. The frequency and aerial extent of violations during the summer months would indicate the violations could not be solely associated with existing point source discharges. The system is poorly flushed with modeling indicating DO criteria would not be met during critical summer months even without point source inputs. Based on this information, it is appropriate to use the 0.1 Rule for evaluation of discharges to the entire system.

Summary of Findings from Analysis of Historic Data

- UBOD loads to the Cooper River have ranged from 50 to 100 percent of the presently proposed permit limits over the past 20 years.
- Dissolved oxygen conditions on the Cooper River on the average are equal to or better than the Ashley and Wando Rivers.
- BOD5 levels on the Cooper River (below the tee) are on the average lower than the levels in the Wando and Ashley Rivers.
- Slight increases in Ammonia concentrations can be seen in the immediate vicinity of the NCSD discharge.
- Areas of peak Nitrate/Nitrite concentrations on the Cooper River do not coincide with the areas of peak Ammonia concentrations.
- Total Nitrogen levels and BOD5 levels show similar spatial characteristics and do not appear to reflect impacts from the discharges.
- The most significant impact upon dissolved oxygen levels (other than water temperature) appears to be non-point source loadings associated with rain events.
- These non-point source load events create conditions where daily average dissolved oxygen levels throughout much of the Lower Cooper River, the Wando River, and
- Therefore under the existing SCDHEC rules and regulations, the maximum allowable anthropogenic dissolved oxygen deficit allowed within these areas is 0.1 mg/L.

ATM

Table 1 Frequency of Violation of Applicable Dissolved Oxygen Criteria

Ashley River

% violation of minimum DO 4

Station	**June**	**July**	**August**	**Sept**	**Oct**
02172081 Ashley at Cooke Crossroads	64.5	62.3	68.3	37.9	16.7
021720869 Ashley near N Charleston	38.3	93.3	79.7	79.7	3.6
02172090 Ashley at Charleston	11.8	57.6	53.3	40.7	0.0

% violation of daily avg DO 5

Station					
02172081 Ashley at Cooke Crossroads	51.6	81.8	88.9	83.9	38.5
021720869 Ashley near N Charleston	NA	NA	NA	NA	NA
02172090 Ashley at Charleston	3.9	34.8	40.0	23.3	1.4

Wando River

% violation of minimum DO 4

Station	**June**	**July**	**August**	**Sept**	**Oct**
021720695 Guerin Creek	80	100	100	82.6	6.3
021720694 Wando at Ward Bridge	46.2	86.8	88.2	64.9	29.2
021720696 Wando at Cainhoy	23.4	73.8	59.6	51.8	0
021720698 Wando at 526	18.1	31.9	58.6	44.9	3.6

% violation of daily avg DO 5

Station					
021720695 Guerin Creek	74.5	100.0	100.0	83.7	11.4
021720694 Wando at Ward Bridge	91.0	95.6	91.8	85.1	39.3
021720696 Wando at Cainhoy	20.3	45.9	55.1	64.7	0.0
021720698 Wando at 526	9.7	26.1	49.4	37.7	3.6

Cooper River

% violation of minimum DO 4

Station	**June**	**July**	**August**	**Sept**	**Oct**
021720011 Tailrace Canal below Lake Moultrie	49.4	74.2	27.2	17.0	0.0
02172040 Back River at Dupont Intake	18.3	25.0	29.0	30.0	0.0
02172037 East Branch Cooper River	2.2	46.6	38.2	37.4	15.2
02172050 Cooper River below the 'T'	0.0	0.0	9.1	2.0	0.0
02172053 Cooper River at Mobay	0.0	10.0	22.0	0.0	0.0
021720675 Cooper River at Army Depot (Goose Cr)	79.5	92.5	88.4	77.0	3.1
021720710 Cooper River at Customs House	0.0	0.0	0.0	0.0	0.0
02172100 Charleston Harbor at Fort Sumter	0.0	12.1	24.3	4.3	0.0

% violation of daily avg DO 5

Station					
021720011 Tailrace Canal below Lake Moultrie	36.1	64.4	19.1	15.9	0.0
02172040 Back River at Dupont Intake	15.0	27.5	35.5	37.5	0.0
02172037 East Branch Cooper River	4.4	29.5	25.5	20.6	3.3
02172050 Cooper River below the 'T'	NA	NA	NA	NA	NA
02172053 Cooper River at Mobay	NA	NA	NA	NA	NA
021720675 Cooper River at Army Depot (Goose Cr)	NA	NA	NA	NA	NA
021720710 Cooper River at Customs House	NA	NA	NA	NA	NA
02172100 Charleston Harbor at Fort Sumter	NA	NA	NA	NA	NA

APPENDIX B

Model Calibration Report

United States Department of the Interior

U.S. GEOLOGICAL SURVEY

Water Resources Division
Stephenson Center, Suite 129
720 Gracern Road
Columbia, SC 29210-7651
Phone: (803) 750-6100
FAX: (803) 750-6181

RECEIVED

JUL 24 2003

BUREAU OF WATER

July 22, 2003

Mr. Jim Greenfield
TMDL Region Coordinator
USEPA-Region IV
61 Alabama Ave .
Atlanta, GA

Dear Mr. Greenfield,

As you requested, I reworked the schematization of the BRANCH flow model of the Ashley River to route the wastewater treatment plant effluent in the flow model and recalibrated the BLTM model to incorporate recent (2000) data on the de-nitrification rate of the system. In addition, I addressed the technical issues received by the South Carolina Department of Health and Environmental Control during the public comment period for the proposed TMDL for the Ashley River. During the recalibration of the model, I worked closely with the staff at SCDHEC and they have been conveyed a copy of the updated models. Enclosed is a summary of the changes to the BRANCH and BLTM models. The text, tables, and figures in the summary corresponds to the section "Calibration and Validation of Nutrients, Biochemical Oxygen Demand, and Dissolved Oxygen" in the report "Simulation of Temperature, Nutrients, Biochemical Oxygen Demand, and Dissolved Oxygen in the Ashley River near Charleston, South Carolina" (U.S. Geological Survey Water Resources Research Investigation Report 98-4150).

Please call me at (803) 750-6140 if you have any questions or need additional information.

Sincerely,

Paul A. Conrads
Hydrologist

cc: Alton Boozer, South Carolina Department of Health and Environmental Control

ENHANCEMENTS TO THE BRANCH FLOW MODEL AND RE-CALIBRATION OF THE BLTM MODEL OF THE ASHLEY RIVER

Background

The BRANCH and BLTM model applications to the Ashley River were used in the development of the Total Maximum Daily Load (TMDL) for the Ashley River. As a result of the development of the TMDL and the public comments to the proposed TMDL, State and Federal Regulatory Agencies requested the models to be modified and recalibrated for addition analysis for the TMDL. This document is a summary of the enhancements to and re-calibration of the Ashley River model as documented in the USGS WRRI report "Simulation of Temperature, Nutrients, Biochemical Oxygen Demand, and Dissolved Oxygen in the Ashley River near Charleston, South Carolina" (Conrads, 1998). The term "re-calibration" is used to refer to the modifications in the rate kinetics of the BLTM Ashley River model rather than including the term "re-validation." All the rate kinetics in the model were held constant for each simulation period.

The text, tables, and figures in this summary and appendix correspond to the section titled, "Calibration and Validation of Nutrients, Biochemical Oxygen Demand, and Dissolved Oxygen" in the report (Conrads, 1998). The section provides a good summary of the data-collection periods and the original approach to model calibration and validation. The tables in this summary update the tables in the section that summarize the parameters used for setting the BLTM model and the model performance for meeting the calibration criteria. Figures 20 – 22 in the report showed the calibration and validation simulation for eight state variables. In the attached appendix, figures 1-3 are modified from these figures and show the calibration/validation simulations of the state variables along with the re-calibration simulations of the variables. Figure 23 in the original report shows the model calibration/validation for the three time series of dissolved-oxygen concentration for the calibration/validation periods. Figures 4 – 6 in the attached appendix show the original time series plots along with the re-calibration plots for the three periods.

Enhancement to the Ashley River BRANCH Model

Many water quality models do not actually route the flows from point sources but rather simulate the effluent input to a receiving stream as a mass loading of particular effluent constituents. In the original schematization of the BRANCH and BLTM, the same approach was used. Constant flows in the BLTM flow file and concentrations for point-source discharges simulated a mass loading to the receiving segment of the model. Since the flows are not routed in the BRANCH flow model, the additional water is not routed downstream from the receiving segment.

In the upper segments of the Ashley River, the discharge from the wastewater treatment plants can be a significant portion of the net flow in the river. The BRANCH model was re-schematized from its original application to route constant flows from wastewater treatment plants. Average flows from the Discharge Monitoring Reports were used for input to the flow model and are shown in Table 1.

Table 1. Facility discharge rates for the calibration and validation periods.
[ft^3/s, cubic feet per second]

Facility	BRANCH Junction	Calibration flow (ft^3/s)	Validation flow (ft^3/s)
Summerville, Kings Grant	1	9.39	9.03
Lower Dorchester, Middleton Place	2	2.63	4.27
Bosch, Pepperhill	3	0.76	2.77
Pierpont, Cummings	4	0.28	0.03

The BRANCH model for the Ashley River was schematized using 6 branches, 5 internal junctions, 24 cross-sections, and 2 external boundaries. In BLTM, numerical dispersion can be minimized by removing internal junctions where there is a single upstream and downstream segment and not an interconnection between segments or a confluence with another river or creek. To minimize numerical dispersion for the BLTM application on the Ashley River (see "Schematization of Models" in WRRI 98-4150, p. 14), four of the internal junctions of BRANCH (junctions 1, 2, 4, and 5) in the schematization of BLTM for the Ashley River were removed.

To route point-source flows in the BRANCH model, constant or time varying flows can only be input into the model at a junction or node. In the BLTM model, point-source discharge is handled as tributary flows and can not be input at a junction or node but must be input at a cross-section. To route discharges from wastewater treatment plants in BRANCH and BLTM, constant nodal flows were simulated at junctions 1 and 2 in the BRANCH model and input into BLTM as tributary flows at the corresponding cross-section. The locations of junctions 1 and 2 were adjusted in the BRANCH model to better represent the physical location of the effluent pipes.

A post-processing routine is used to convert the BRANCH model flow output to an input flow file for BLTM. Four internal junctions are removed, the increase in the routed flow due to the constant nodal flow is computed and input into the BLTM flow files as a tributary flow, and the BRANCH 15-minute output is averaged to an hourly input to BLTM in the post-processing routine. In addition to routing the point-source flows, the post-processing step has the advantage of minimizing the numerical dispersion, decreasing simulation run-times, and decreasing output file sizes.

For the calibration period of September 25, 1992, the average difference between the simulated calibration and re-calibration streamflow values ranged from less than 0.7 percent at the Bacons Bridge measuring site to less than 0.1 percent at the other three measurement sites. For the validation period of July 28, 1992, the average difference between simulation validation and re-validation values ranged from less than 0.4 percent at the measurement site at Highway 17 to less than 0.1 percent at the measurement sites at Middleton Place and I-526.

Recalibration of the Ashley River BLTM Model

During the public comment period, some technical concerns of the application BLTM model were identified. After modifying the BRANCH model to simulate the wastewater treatment plant discharges, the technical concerns with the BLTM model were addressed. Specifically, areas of concern were the light attenuation factor and the sediment oxygen demand rate. The following text addresses these concerns and describes the original calibration and validation data sets and changes to the original calibration rate kinetics.

Review of the Calibration and Validation Data Sets

Ten parameters were simulated using the BLTM for the Ashley River: water temperature, dissolved oxygen, algal biomass, organic nitrogen, ammonia, nitrite, nitrate, organic phosphorus, dissolved phosphorus, and $CBOD_u$. The water-quality parameter of most interest to the SCDHEC is dissolved oxygen. Dissolved-oxygen concentration is dependent on many factors, including water temperature, streamflow, atmospheric reaeration, photosynthesis, plant and animal respiration, BOD, nitrification, and benthic oxygen demand. The wastewater permittees discharge ammonia and BOD into the Ashley River; both parameters have a significant effect on dissolved-oxygen concentration.

Four datasets were collected on the Ashley River during the summers of 1992 and 1993 and there are significant differences in the datasets from the two summers. Two sets of data were collected during the summer of 1992 at six sampling stations throughout the modeled reach; however, the analyses did not include chlorophyll-a, an indicator of the algal biomass concentration. The analyses did include nitrite in addition to nitrate concentrations. The level of detection for ammonia was 0.01 mg/L. For the July 1992 dataset, significant amounts of the continuous dissolved-oxygen concentration data were missing so a simulation dataset was not created for this period. The datasets for the summer of 1993 included chlorophyll-a analyses at the lower three stations of the river only. (The sampling of the lower reaches of the Ashley River in 1993 was part of a sampling survey of Charleston Harbor and the lower reaches of the Ashley, Cooper, and

Wando Rivers.) The water-quality analyses for 1993 did not include nitrite and the level of detection for ammonia was 0.05 mg/L.

The BLTM was calibrated using nutrient data collected August 23-25, 1993, and September 25, 1992, and validated using the nutrient data collected May 4-5, 1993. The critical period for dissolved oxygen is during the warm summer months. The August 1993 and September 1992 datasets were used for calibration because they closely approximated the "critical conditions" used for wasteload allocation. Because the model will ultimately be used to determine wasteload allocations for ammonia, BOD, and dissolved oxygen, emphasis was placed on satisfactory simulations of these constituents during calibration and validation.

Thirty-day datasets for the ten modeled constituents (temperature, algae biomass, organic nitrogen, ammonia, nitrate, nitrite, organic phosphorus, dissolved phosphorus, BOD, and dissolved oxygen) were generated for each boundary of the model for the calibration and validation periods. Continuous (hourly) temperature and dissolved-oxygen data were used at the external boundaries. For the other eight constituents, concentration data at station 02172090 were averaged and used as the downstream steady-state boundary concentration for the 1992 and 1993 datasets. Upstream boundary data were not collected at station 02172081 in 1993, therefore, SCDHEC monthly monitoring data were taken from STORET for boundary data for the two 1993 datasets. Data of daily high and daily low air temperatures and wind speed from the Charleston airport were used to estimate the necessary meteorological input data for each dataset of wind speed, equilibrium temperature, and solar radiation (National Oceanic and Atmospheric Administration, 1993a-d). Point-source effluent concentrations during the sampling periods were obtained from the monthly Discharge Monitoring Reports submitted by the NPDES permit holders to SCDHEC. These data were averaged over the calibration and validation dataset periods and entered into the model as point-source loads.

Re-calibration of BLTM Rate Kinetics

The water-quality model was calibrated by adjusting constant (global) and variable (local) kinetic rate coefficients within ranges described by Bowie and others (1985) and Brown and Barnwell (1987) until the simulated constituent concentrations approximated the measured concentrations. Simulated concentrations were considered acceptable when the average simulated constituent concentrations for the period of observed data fell within the range of observed concentrations for a given location. The general approach to calibration of the model was to use the August 1993 dataset to calibrate the algal dynamics and nutrient cycling of the lower reaches of the river and then use the September 1992 data to calibrate the entire river. The algal concentration used in the August 1993 dataset was assumed for the September 1992 dataset. Nitrite concentrations of the September 1992 dataset were used to set the reaction rates for the biological oxidation of ammonia to nitrite (BET1) and for the biological oxidation of nitrite to nitrate (BET2). Kinetic rate coefficients used in the re-calibrated model and recommended values are listed in table 2.

The light extinction factor listed in table 8 of the report contained a typographical error; the rate listed was 0.1 per meter and should have been the 0.7 used in the model. The sediment oxygen demand rate (SOD, coefficient CK4 in BLTM) was originally set at 6.0 milligrams oxygen per square foot per day (mg $O/ft^2/d$). Typical units for SOD are grams of oxygen per square meter per day (g $O/m^2/d$). In the publication "Rates, Constants, and Kinetics Formulations in Surface Water Modeling" (Bowie and other, 1985), SOD rates for estuarine mud are 1-2 grams of oxygen per square meter, which would be the equivalent of 93 to 186 milligrams of oxygen per square foot. The SOD rate (CK4) was changed from a constant value of 6 to a range of 15 to 105 milligrams oxygen per square foot with values increasing from the upper riverine segments to the lower estuarine segments.

The increased CK4 rate increased the sinks of dissolved oxygen in the original calibration. The other sinks of oxygen in the model were re-evaluated to establish a balance in the sources and sinks of oxygen that approach the instream dissolved-oxygen concentration of the Ashley River. The carbonaceous biochemical oxygen demand rate (CK1) used in the calibration was 0.06 per day. This rate was consistent with the rate used in the BLTM model of the Cooper and Wando Rivers (Conrads and Smith, 1996). Measured rates for the Ashley River from the sampling in 1992 and 1993 (Conrads and others, 1995) ranged from 0.02 to 0.07 per day. The CK1 rates were averaged for each site over the sampling period. The resulting rates were 0.03 to 0.05 with the higher values occurring in the lower segments of the river. With the lower CK1 rate, the simulated instream concentrations of biochemical oxygen demand (BOD) were higher than the measured values. To lower the instream concentration, the benthos source rate for BOD (CK5) was lowered from 70 milligrams BOD per square foot per day to between 1 to 40 milligrams BOD per square foot per day. Values generally increased from the upper segments to the lower segments.

In 2001 as part of the TMDL evaluation on the Cooper River, nitrification rates were determined for a number of locations on the Ashley, Cooper, and Wando Rivers and Charleston Harbor (Applied Technology and Management, 2002). The nitrification rates varied from 0.004 to 0.121 per day with the higher rate measured on the Ashley River. Although these rates are for conditions in the estuary for 2001 and may not reflect conditions during the calibration and validation data collection periods in 1992 and 1993, the measured rates are better values than the rates set during the original calibration. These measured rates are approximately an order of magnitude less that the nitrification rates used in the calibration of the model.

In the QUAL2E sub-model of BLTM, there are over twelve sources, sinks, or kinetic rate terms that control the cycling of nitrogen. For the original calibration of the model, direct measurements of the rate kinetics were not available. A change by an order of magnitude of the nitrification rate kinetic necessitates the re-evaluation of the other rate kinetics and source and sink terms that characterize the nitrogen cycle in the model. Decreasing the nitrification rate without adjusting any other of the rate terms in the nitrogen cycle, resulted in greatly increased ammonia nitrogen concentrations. In

QUAL2E, ammonia is converted to nitrate in a two-stage process. Recommended rate kinetic values for the biological oxidation of ammonia to nitrite (BET1) are half of the biological oxidation of nitrite to nitrate (BET2). As these rates were adjusted during the re-calibration process, the ratio between these rates was maintained. In order to simulate reasonable concentration of ammonia, other rates in the cycling process were adjusted including the maximum specific growth rate, respiration, algal preference factor for ammonia, and benthic sources rate for organic nitrogen and ammonia. Kinetic rate coefficients used in the re-calibrated model and recommended values are listed in table 2.

Table 2. Rate constant coefficients, recommended values, and values used in the Branched Lagrangian Transport Model (BLTM) for the Ashley River, S.C. (Supercedes Table 6 in Conrads, 1998)

[--, no units]

Coefficient	Recommended values	Values used	Units	Coefficient description
A1	3.01	3.01	millimeter per day Kpa	Free convection - wind
ALGSET	0.50-6.00	0.00	feet per day	Local settling rate for algae
ALPH0	10.0-100.0	67.0	milligrams chlorophyll-A per milligram algae	Ratio of chlorophyll-a to algal biomass
ALPH1	0.07-0.09	0.09	milligrams nitrogen per microgram algae	Fraction of algal biomass that is nitrogen
ALPH2	0.01-0.02	0.020	milligrams phosphorus per microgram algae	Fraction of algal biomass that is phosphorus
ALPH3	1.40-1.80	1.40	milligrams oxygen per microgram algae	Oxygen production per unit of algal growth
ALPH4	1.60-2.30	2.30	milligrams oxygen per microgram algae	Oxygen uptake per unit of algae respired
ALPH5	3.00-4.00	3.43	milligrams oxygen per milligram nitrogen	Oxygen uptake per unit of ammonia oxidized
ALPH6	1.00-1.14	1.14	milligrams oxygen per milligram nitrogen	Oxygen uptake per unit of nitrite oxidized
B1	1.13	1.13	Millimeters per day per kilipascal per meter per second	Mass-transfer coefficient
BET1	0.1-1.0	0.20	per day	Biological oxidation rate of ammonia to nitrite
BET2	0.20-2.00	0.40	per day	Biological oxidation of nitrite to nitrate
BET3	0.02-0.40	0.02	per day	Hydrolysis rate of organic nitrogen to ammonia
BET4	0.01-0.70	0.021	per day	Decay rate of organic phosphorus to dissolved phosphorus
CK1	0.02-3.40	0.03-0.05	per day	Carbonaceous BOD decay rate
CK2	0.0 - 100.0	0.14-0.25	per day	Reaeration rate
CK3	-0.36 - 0.36	0.00	per day	Carbonaceous sink rate of BOD
CK4	variable	15-105	milligrams oxygen per square foot per day	Benthos oxygen consumption rate
[1]CK5		1-40	milligrams BOD per square foot per day	Benthos source rate for BOD
CKL	0.02-0.10	0.02	Langley per minute	Light half-saturation constant for algae
CKN	0.01-0.30	0.26	milligrams per liter	Nitrogen half-saturation constant for algae
CKP	.001-.05	0.04	milligrams per liter	Phosphorus half-saturation constant for algae
GRO	1.00-3.00	3.00	per day	Maximum specific growth rate

Table 2. Rate constant coefficients, recommended values, and values used in the Branched Lagrangian Transport Model (BLTM) for the Ashley River, S.C. (Supercedes Table 6 in Conrads, 1998) --continued

Coefficient	Recommended values	Values used	Units	Coefficient description
IGRO	Option 1, 2	2	--	Growth rate option
K20	Options 1-8		--	Reaeration option (option 4—Owens and others, 1964)
LFO	Option 1,2	Option 1	--	Light function option (option 1--half saturation)
[1]NO2L	0.00-1.00	0.20	--	Nitrate loss factor
PN	0.00-1.00	0.70	--	Algal preference factor for ammonia
RSPRT	0.05-0.50	0.25	per day	Algal respiration rate
SHAD0	variable	0.7	per meter	Light extinction
SHAD1	.002-0.02	0.01	per meter per microgram-chlorophyll-A per liter	Linear self shading
SHAD2	0.0165	0.017	per meter per (microgram-chlorophyll-A per liter)$^{2/3}$	Non-linear self shading
SIG2	variable	1.50-3.00	Milligrams phosphorus per day per meter	Benthos source rate for dissolved phosphorus
SIG3	variable	1.25	Milligrams nitrogen per square foot per day	Benthos source rate for ammonia
SIG4	.001-.10	0.0	per day	Organic nitrogen settling rate
SIG5	.001-0.10	0.00	per day	Organic phosphorus settling term, per day
[1]SIG6		2.0-2.5	per day	Benthos source rate for organic nitrogen, per day
[1]SIG7		0.03-0.04	per day	Dissolved phosphorus settling rate, per day

[1] Variable added for Cooper and Wando River study. No recommended values available.

Re-calibration Model Performance

For the calibration and validation simulations, model output for each constituent consisted of hourly values over a 30-day period (720 simulated data points). Measured data for the September 1992 calibration datasets were limited to five data points for each constituent at approximately 3-hour intervals over a single 12-hour sampling period representing half of the semi-diurnal tide cycle. The August 1993 calibration dataset and May 1993 validation dataset consist of five data points for each constituent at approximately 12-hour intervals (high- and low-slack tides) over 2 or 3 days. Only those simulated data that corresponded to the time of measured data were used To evaluate the model output. Therefore, for each 30-day simulation, only the simulated data concurrent with the measured data were averaged and compared with the measured data. The criterion used to evaluate calibration and validation of the model was a target range bracketed by the maximum and minimum concentrations of the measured data. This criterion was considered achieved when the simulated mean fell within the range of the measured data. Simulated means also were compared to a calculated range 20 percent larger than the actual measured range to include those simulated means that did not meet the defined criterion, but were considered close to meeting it. A standard deviation was calculated for simulated data over this period in order to compare the simulated constituent concentration variability with actual measured data variability.

Measured ammonia concentrations for the 1993 dataset were equal to or less than 0.05 mg/L, the lower limit of detection for the analysis, for 29 of the 30 analyses. Because there was no variability to the measured data, the evaluation criterion could not be applied. Therefore, the range from 0.04 to 0.06 mg/L was defined as the evaluation criterion for the simulated mean ammonia concentrations.

Results of the water-quality model re-calibration are presented as longitudinal profiles of constituent concentrations versus river mile (appendix - figs. 1, 2, 3) and as hydrographs of dissolved-oxygen concentration versus time for gaging station 021720869 (appendix - figs. 4, 5, 6). To facilitate comparison between the original calibration and the re-calibration, each plot shows either the original calibration or validation simulation with the re-calibration simulation. The mean simulated values and one standard deviation are shown with the minimum and maximum observed values except for the ammonia values where the measured data were at or below 0.05 mg/L, the limit of detection. The percent of stations meeting the calibration and validation criterion and expanded criterion for each constituent is shown in table 3.

Table 3. Percent of stations meeting calibration and validation criteria for nine Constituents (Supercedes Table 7 in Conrads, 1998)
[$CBOD_u$, ultimate carbonaceous oxygen demand]

Constituent	Calibration simulations (September 25, 1992) (August 23-25, 1993)		Validation simulation (May 4-5, 1993)	
	Stations meeting criterion[1] (percent)	Stations meeting expanded criterion[2] (percent)	Stations meeting criterion[1] (percent)	Stations meeting expanded criterion[2] (percent)
[3]Algal biomass	100	100	100	100
Organic nitrogen	89	100	100	100
Ammonia nitrogen	33	33	100	100
[4]Nitrite nitrogen	67	89	--	--
Nitrate nitrogen	33	33	33	66
Organic phosphorus	66	66	100	100
Dissolved phosphorus	100	100	100	100
$CBOD_u$	89	89	66	66
Dissolved oxygen	78	78	66	100

[1] Mean simulated constituent concentration during sampling period within the range of the minimum and maximum measured concentration.
[2] Mean simulated constituent concentration during sampling period within a range twenty percent larger that the range of the minimum and maximum measured concentration.
[3] May and August 1993 datasets only.
[4] September 1992 dataset only.

The simulations for the re-calibration dataset of September 1992 show that there is little difference between the calibration and re-calibration simulations for the state variables of concern. Both simulations generally follow the longitudinal trends of the measured data (appendix -fig. 1). The re-calibration model better simulated the high ammonia concentrations measured at Middleton Place (river mile 20.1, appendix - fig. 1) but over simulated the lower concentrations in the lower reaches of the river. The critical area for the TMDL application is the upper Ashley River. Measured data for the Upper Ashley are limited to the September 1992 period. The model captures the higher ammonia levels on the upper Ashley during this period. The model over-predicts nitrate concentrations for the September 1992 and the August 1993 periods. Nitrate is not a high priority constituent for the TMDL application of the model where the phytoplankton routine will not be utilized. The sensitivity analysis in the original report indicated that simulated dissolved-oxygen concentrations were relative insensitive to changes in the nitrate boundary conditions. The $CBOD_u$ simulations (appendix - fig. 1) followed the trend of the measured data with higher concentrations in the upstream reaches of the Ashley River and decreasing concentrations downstream. The mean of the dissolved oxygen simulations (appendix - fig. 1) were generally within the range of the measured data, but over simulated the decreasing dissolved-oxygen at Middleton Place (river mile 20.1). For the August 1993 calibration simulations (appendix - fig. 2), there is little difference between the calibration and re-calibration simulations and the nutrient simulations follow the measured trends for the lower reach of the river. For some of the longitudinal profiles, there is a significant difference in the simulated profiles in the upper reaches of the system but sampling data are not available to confirm either profile.

The validation simulations of the May 1993 (appendix - fig. 3) dataset show the mean simulated concentrations generally falling within the range of the measured concentrations for both the validation and re-calibration simulations. The algal biomass concentrations, although within the range of the measured data, are near the lower range of the measured concentrations. As with the August 1993 simulations, there is a significant difference in the simulated profiles in the upper reaches of the system but data are not available to confirm either profile. The model under-simulated the CBODu concentrations and slightly over-predicted the measured dissolved-oxygen concentrations (appendix - fig. 3).

In addition to comparing the simulated dissolved-oxygen concentrations to the measured field readings during the nutrient sampling, time series of simulated dissolved-oxygen concentrations from the re-calibration model were compared with measured dissolved-oxygen concentrations from station 021720869. There were two significant differences in the methods used for collecting dissolved-oxygen data from the gaging station as compared to the dissolved-oxygen profiles measured during the nutrient sampling. First, the probes for the gaging stations were set at fixed elevations that did not vary with changes in water level. Station 021720869 was instrumented with two sets of probes, the probes were set approximately one meter from the bottom and one meter below the mean low-water elevation. The values from the two probes were averaged to compute a mean value. The dissolved-oxygen profiles measured during the nutrient sampling were recorded at one-meter intervals from the water surface. Second, the gaging station was attached to bridge pier located near the center channel whereas the sampling profiles were taken in the center channel of the Ashley River.

As with the other comparison plots of the calibration/validation and re-calibration simulations, the dissolved-oxygen concentration time series plots show little difference between the calibration and re-calibration. The 4-day simulation from September 22-25, 1992, shows that simulated dissolved-oxygen concentrations closely followed the measured dissolved-oxygen concentrations, but the simulated concentration did not show the slight decreasing trend of the measured data (appendix - fig.4). The average measured concentration was 4.0 mg/L with a standard deviation of 0.2 mg/L as compared to an average simulated concentration of 4.1 mg/L and a standard deviation of 0.10 mg/L (the calibration simulation had a mean of 3.8 mg/L and a standard deviation of 0.0 mg/L). The simulations for May 1-7 and August 19-25, 1993 (appendix - fig. 5 and 6), are within the range of the measured data but do not simulate the variance. Comparison of the mean simulated and measured concentrations are 6.4 and 6.7 mg/L and 4.0 and 3.7 mg/L, respectively, whereas the standard deviation of the two periods differ by an order of magnitude, 0.1 and 0.04 mg/L and 0.07 and 0.50 mg/L respectively, for the two periods (the mean and standard deviations of the May 1993 and the August 1993 validation and calibration periods were 6.5/.05 mg/L and 3.9/.04 mg/L, respectively).

The model simulates the longitudinal dissolved-oxygen trend reasonably well. As noted above, the model over-predicts the dissolved-oxygen concentrations at River Mile 20.1. The model was not able to capture the decreasing trend in the time-series for the May 1993 period, but was able to capture the trend during the warmer months of the August 1993 and September 1992 periods, which are of greater interest for the TMDL application. The model did not capture the diurnal variability of the dissolved-oxygen time series. This would limit the use of the model for evaluating scenarios assess impact to daily minimum concentrations. This would not preclude the use of the model for assessing relative impacts on daily mean concentrations including evaluating allowable impacts of 0.10 mg/L.

Summary

The BRANCH and BLTM models of the Ashley River that were developed during the mid-1990s (Conrads, 1998) were modified and recalibrated at the request of State and Federal Regulatory Agencies for the use in developing a TMDL for the river. Point-source loading to the original model was simulated as a mass loading of oxygen consuming constituents. Because of the small net tidal flows of the upper Ashley River, the model was enhanced to accommodate routed flows from the point-source dischargers in the flow model. Recent (2000) data on the de-nitrification rate kinetic was also incorporated into the model. The measured de-nitrification rate was approximately an order of magnitude less than the rate determined during the original calibration process. The adjustment of the rate mandated the re-valuation of the rate kinetics related to nitrogen cycling. Technical issues received by the State Regulatory agency during the public comment period for the TMDL were also addressed during the recalibration of the model.

The enhancements to the flow model and the recalibration to the water-quality model made little difference to the model performance reported in the original report. Differences in the flow model between simulated flows using the original model and the point-source flow routed model were less than 0.7 percent for the upper reaches of the model and less than 0.1 percent at other locations through the model domain. The differences in the water-quality simulations between the original model and the re-calibrated model were small for the state variables of concern. The recalibrated model over simulates nitrate concentrations. The recalibrated model simulates the longitudinal dissolved-oxygen trends and the daily dissolved-oxygen concentrations reasonably well but does not simulate the diurnal variability of dissolved-oxygen particularly well.

SELECTED REFERENCES

Applied Technology and Management, 2002,"Development of a Wasteload Allocation Model within the Charleston Harbor Estuary Part II- Water Quality", prepared for South Carolina Department of Health and Environmental Control, July 9, 2002

Bowie, B.L., Mills, W.B., Porcella, D.B., Campbell, C.L., Pagenkopf, J.R., Rupp, G.L., Johnson, K.M., Chan, P.W.H., Gherini, S.A., and Chamberlin, C.E., 1985, Rates, constants, and kinetics formulation in surface water quality modeling, 2nd ed.: U.S. Environmental Protection Agency, EPA/600/3-85/040, 55 p.

Brown, L.C., and Barnwell, T.O., Jr., 1987, The enhanced stream water quality models QUAL2E and QUAL2E-UNCAS—Documentation and user manual: Athens, Georgia, U.S. Environmental Protection Agency, Environmental Research Laboratory, EPA/600/3-87/007, 189 p.

Conrads, P.A., 1998, Simulation of temperature, nutrients, biochemical oxygen demand, and dissolved oxygen in the Ashley River near Charleston, South Carolina: U.S. Geological Survey Water-Resources Investigations Report 98-4150, 56 p.

Conrads, P.A., and Smith, P.A., 1997, Simulation of temperature, nutrients, biochemical oxygen demand, and dissolved oxygen in the Cooper and Wando Rivers near Charleston, South Carolina, 1992-95: U.S. Geological Survey Water-Resources Investigations Report 97-4151, 58 p.

Jobson, H.E., 1997, Enhancements to the Branched Lagrangian Transport Modeling System: U.S. Geological Survey Water-Resources Investigations Report 97-4050, 56 p.

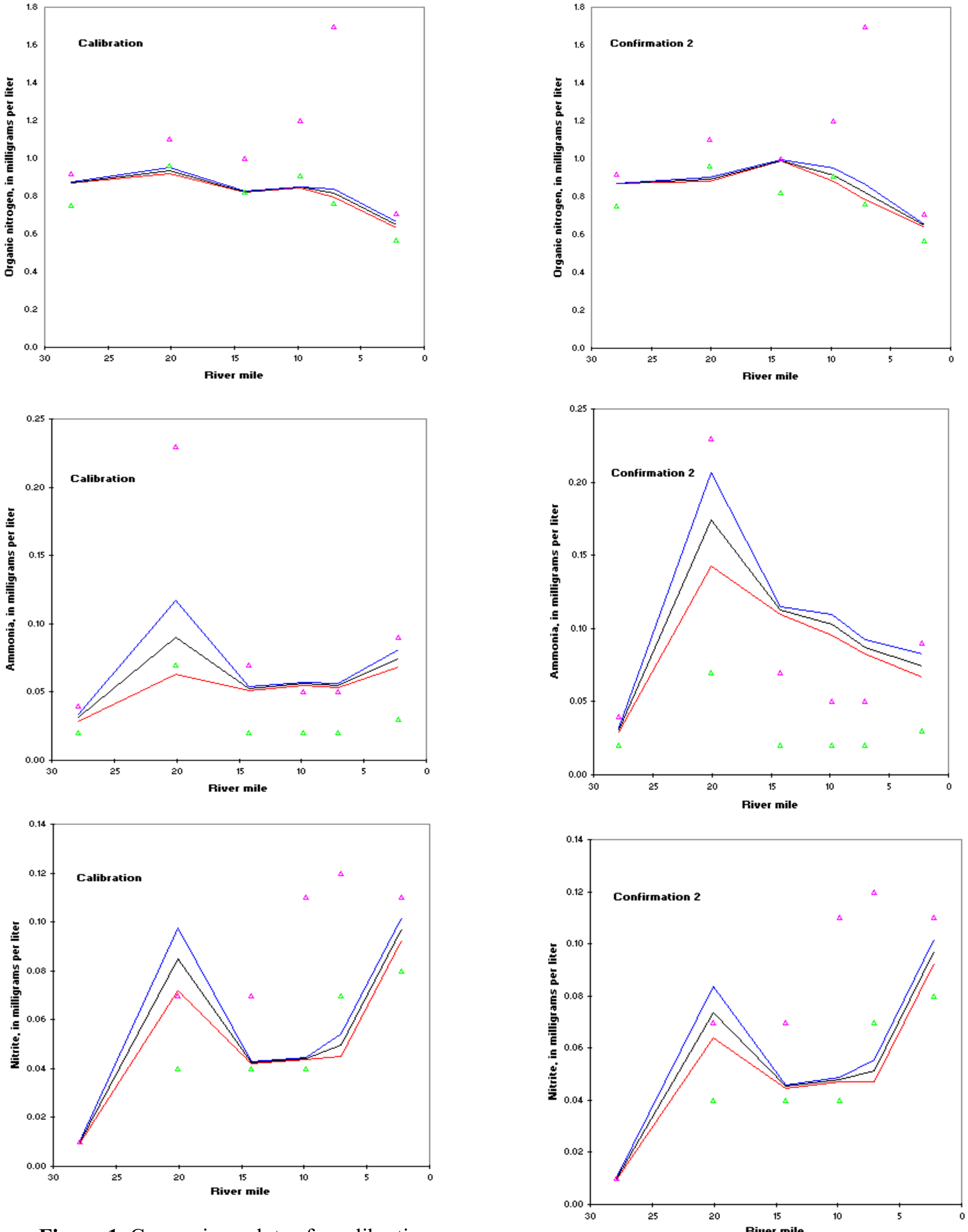
Jobson, H.E., and Schoelhamer, D.H., 1987, User manual for a Branched Lagrangian Transport Model: U.S. Geological Survey Water-Resources Investigations Report 87-4163, 73 p.

Schaffranek, R.W., Baltzer, R.A., and Goldberg, D.C., 1981, A model for simulation of flow in singular and interconnected channels: U.S. Geological Survey Techniques of Water-Resources Investigations Book 7, Chapter C3, 110 p.

APPENDIX 1

Figures for:

ENHANCEMENTS TO THE BRANCH FLOW MODEL AND RE-CALIBRATION BLTM MODEL OF THE ASHLEY RIVER



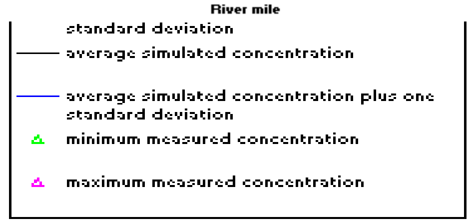


Figure 1. Comparison plots of recalibration, September 25, 1992 for organic nitrogen, nitrite, and nitrate. Figure based on figure 21 in WRRI 98-4150.

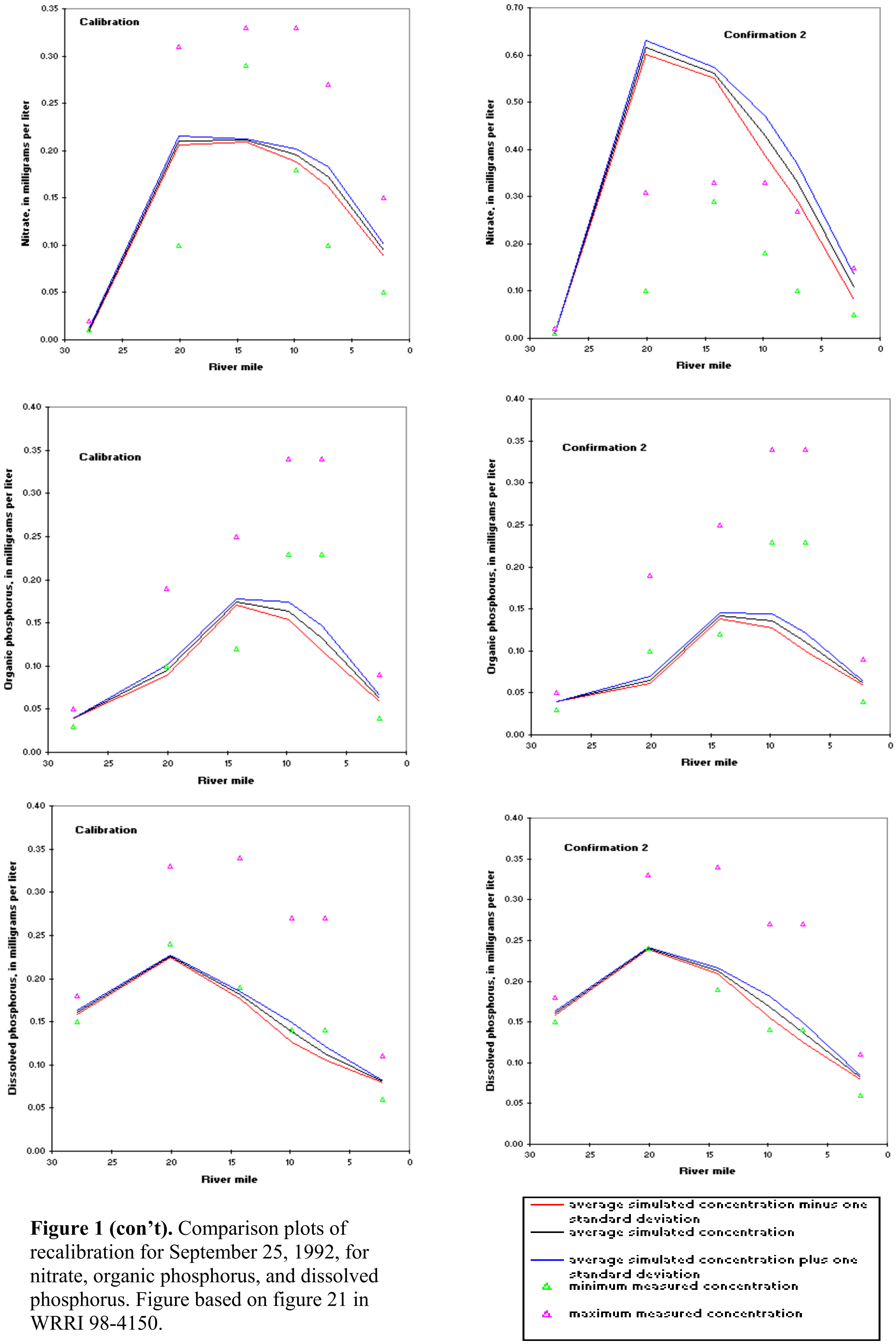


Figure 1 (con't). Comparison plots of recalibration for September 25, 1992, for nitrate, organic phosphorus, and dissolved phosphorus. Figure based on figure 21 in WRRI 98-4150.

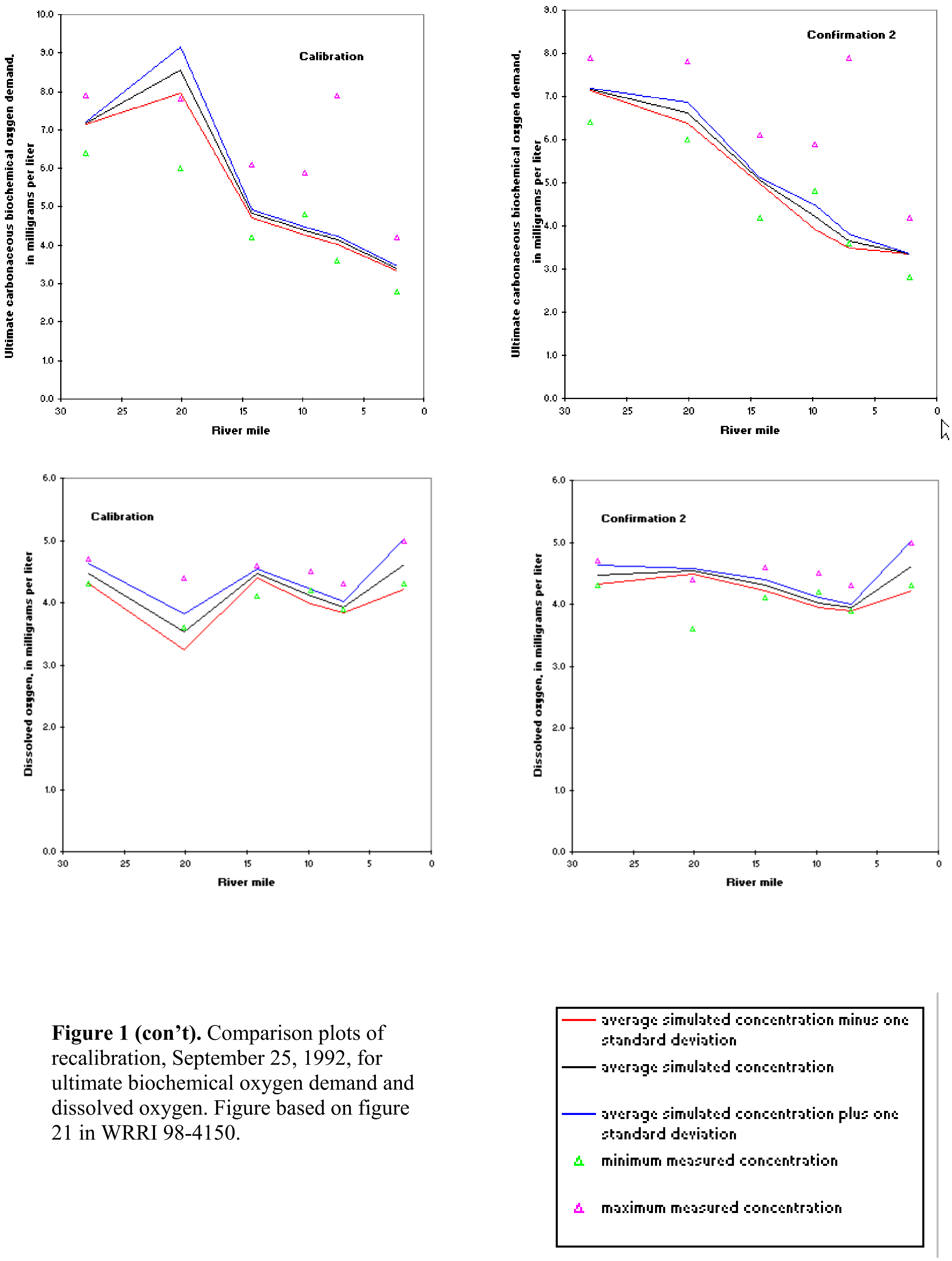


Figure 1 (con't). Comparison plots of recalibration, September 25, 1992, for ultimate biochemical oxygen demand and dissolved oxygen. Figure based on figure 21 in WRRI 98-4150.

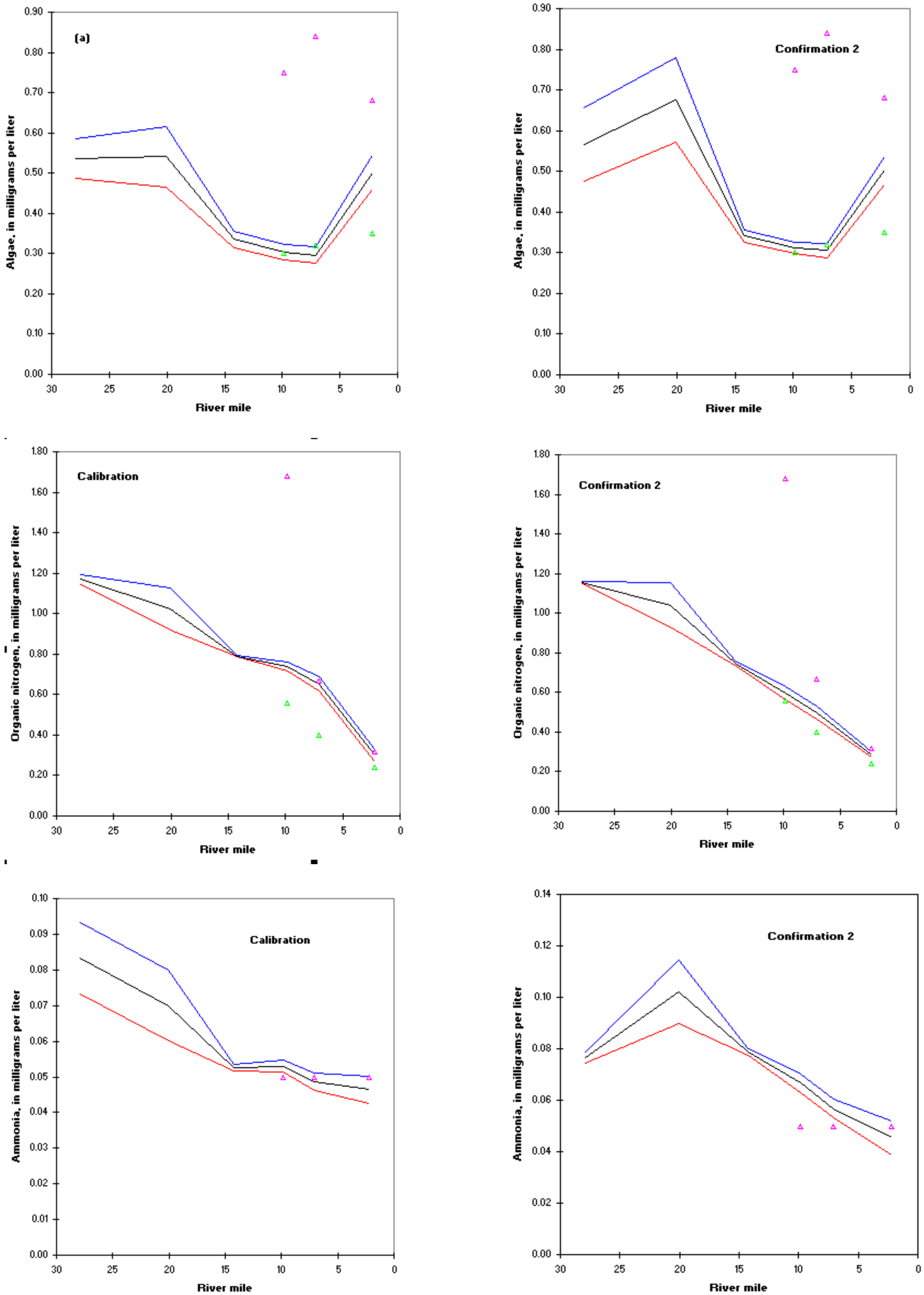
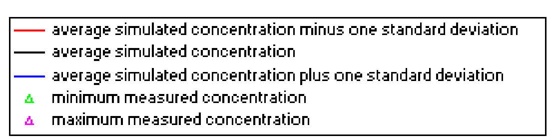


Figure 2. Comparison plots of recalibration for algal biomass, organic nitrogen, and ammonia August 23-25, 1993. Figure based on figure 20 in WRRI 98-4150.



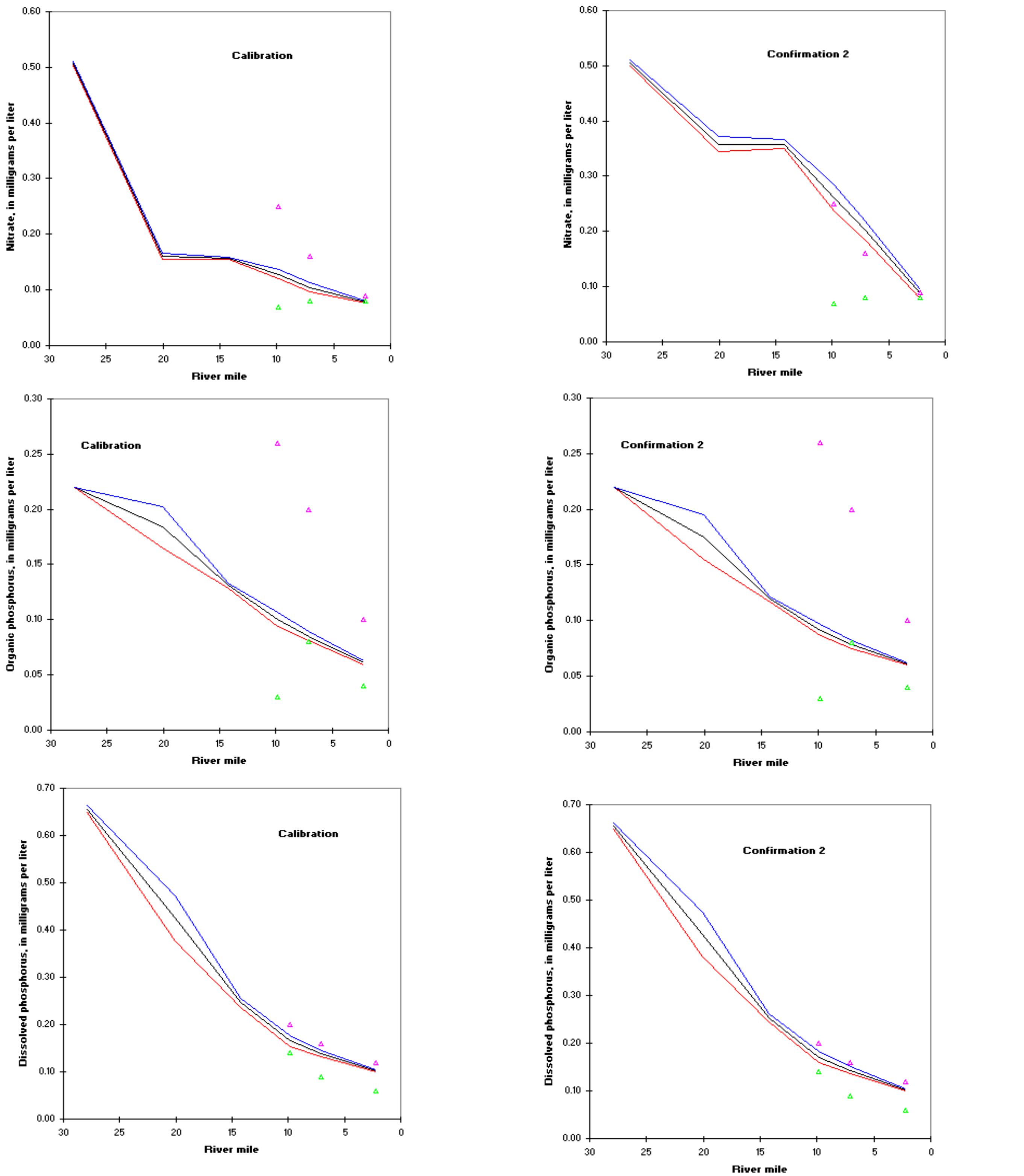
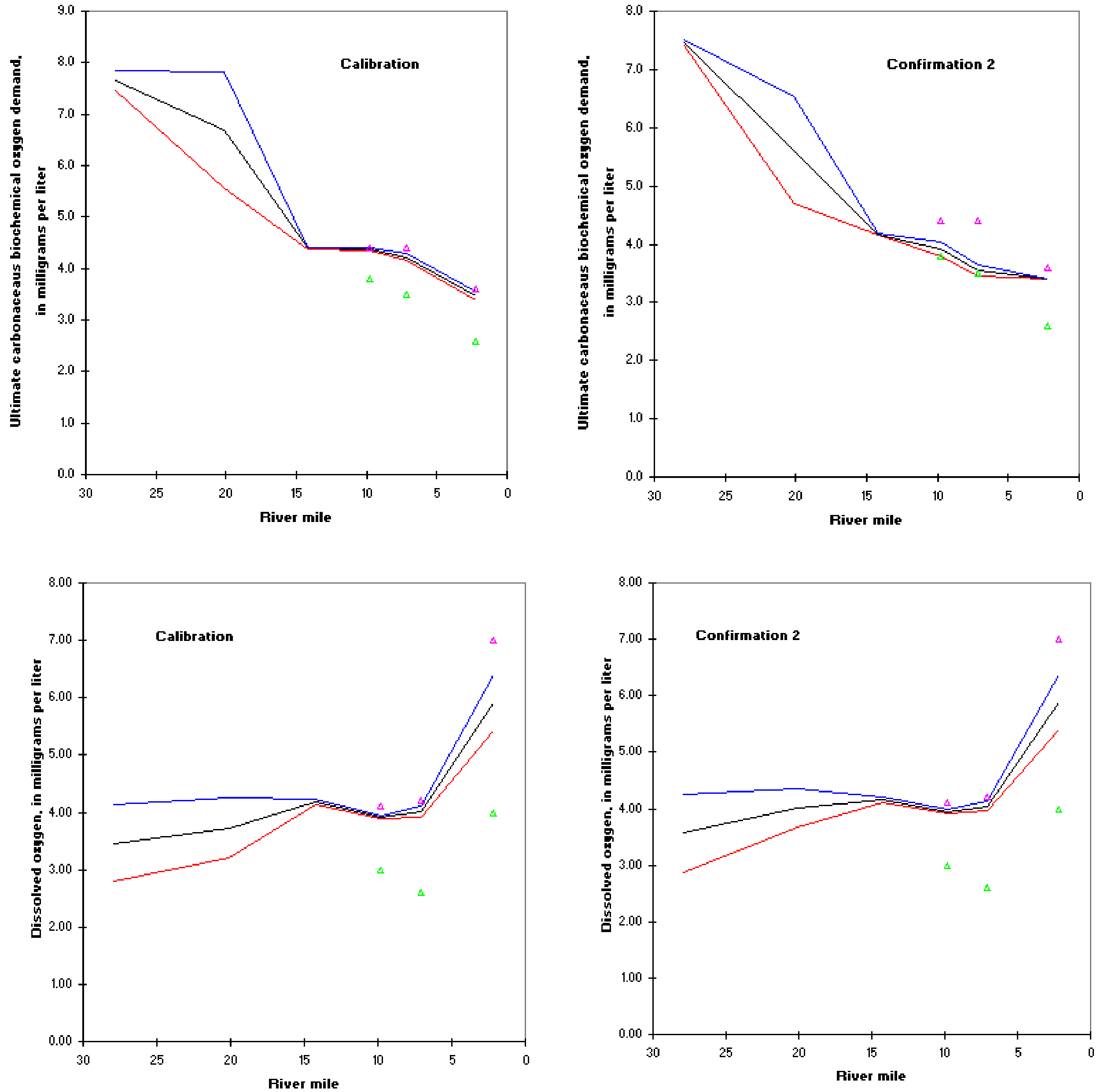


Figure 2 (con't). Comparison plots of recalibration, August 23-25, 1993, for nitrate, organic phosphorus, and dissolved phosphorus. Figure based on figure 20 in WRRI 98-4150.



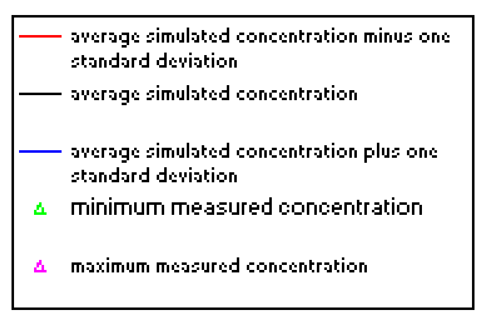


Figure 2 (con't). Comparison plots of recalibration, August 23-25, 1993, for ultimate-biochemical oxygen demand and dissolved oxygen. Figure based on figure 20 in WRRI 98-4150.

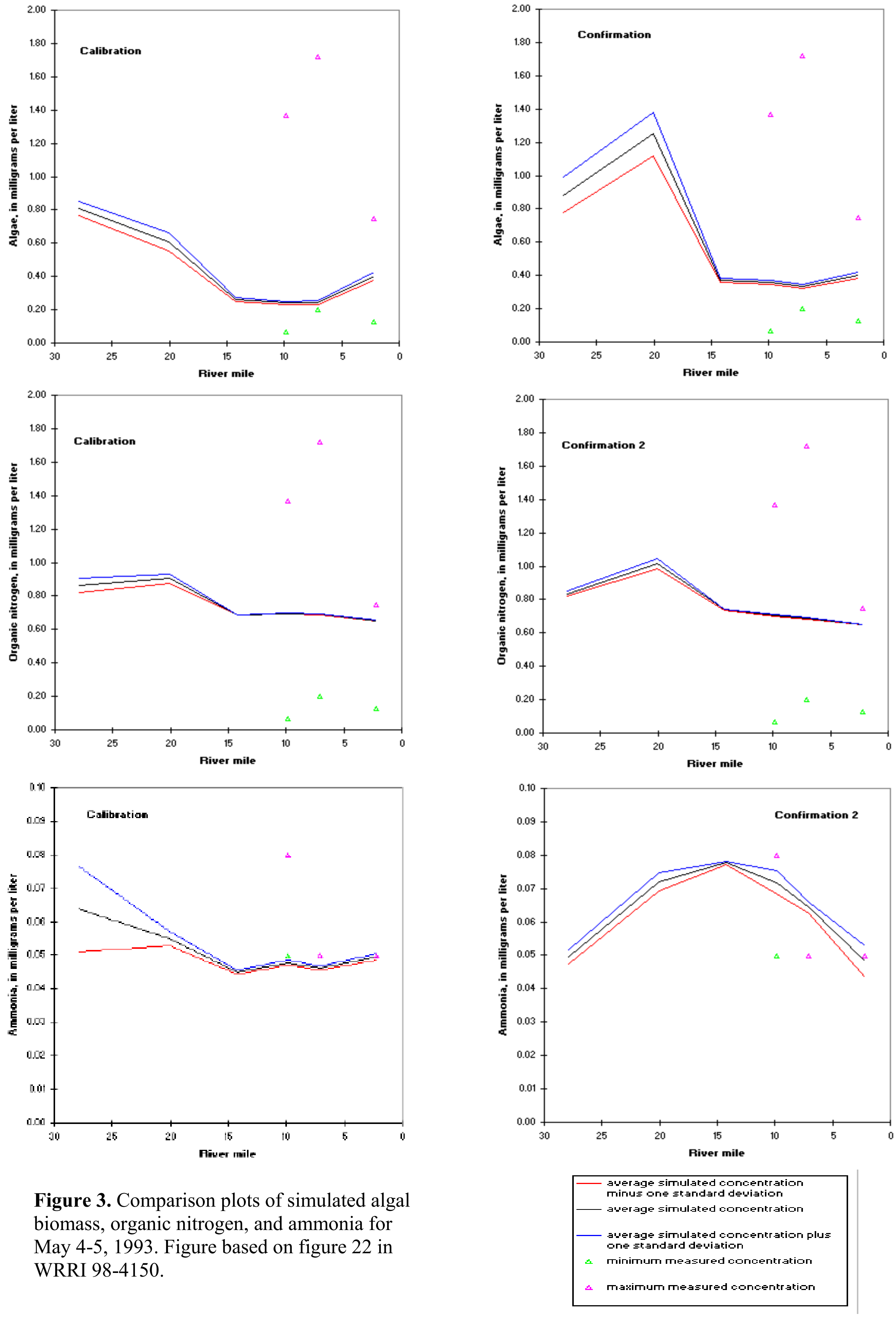
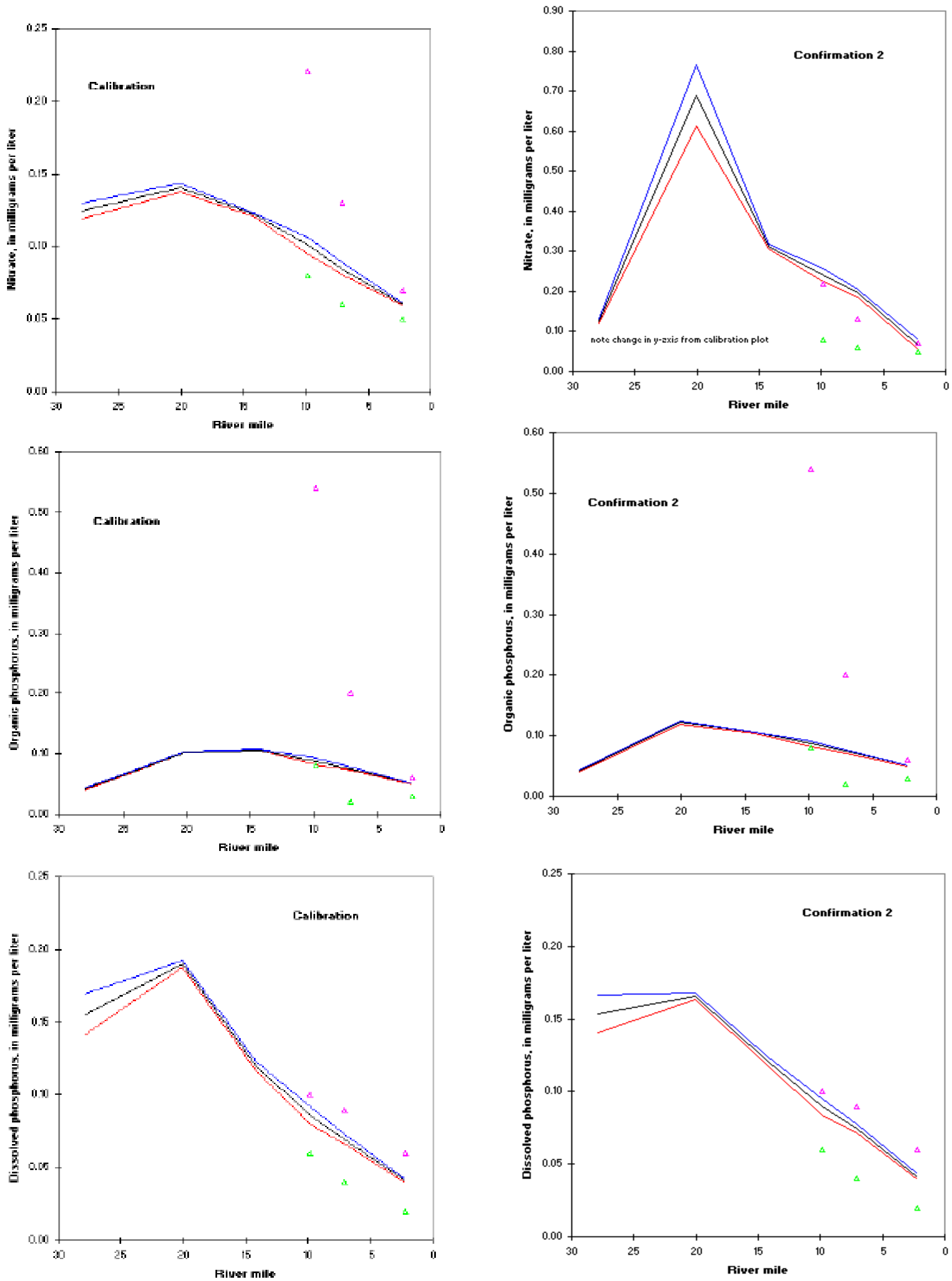


Figure 3. Comparison plots of simulated algal biomass, organic nitrogen, and ammonia for May 4-5, 1993. Figure based on figure 22 in WRRI 98-4150.



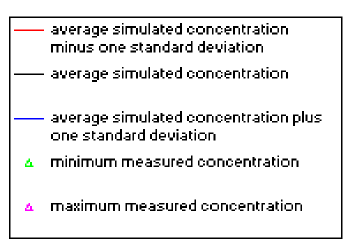


Figure 3 (con't). Comparison plots of simulated nitrate, organic and dissolved phosphorus for May 4-5, 1993. Figure based on figure 22 in WRRI 98-4150.

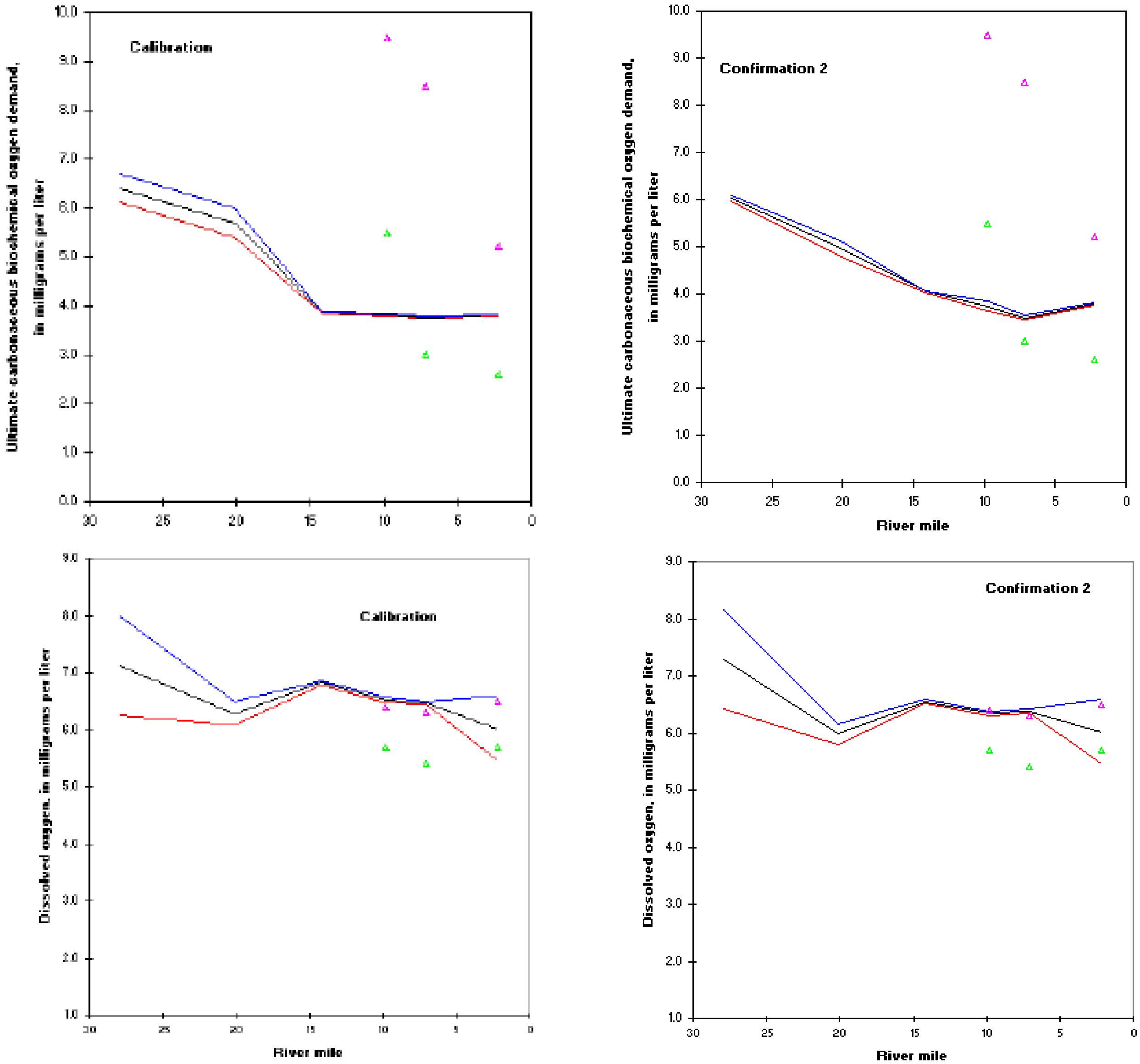


Figure 3 (con't). Comparison plots of simulated ultimate biochemical oxygen demand and dissolved oxygen for May 4-5, 1993. Figure based on figure 21 in WRRI 98-4150.

Explanation

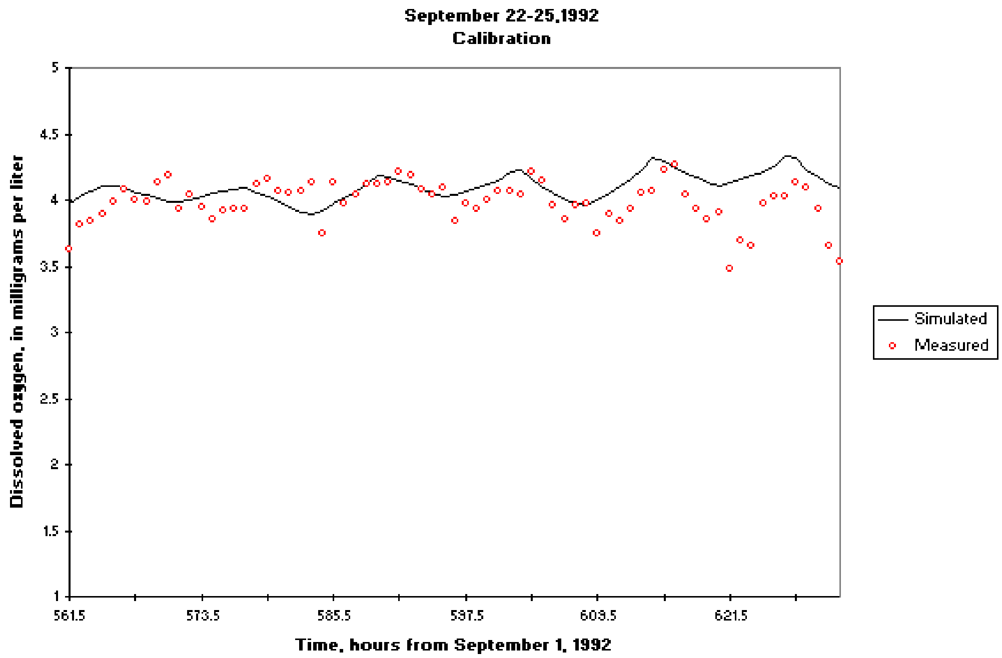
average simulated concentration minus one standard deviation

average simulated concentration

average simulated concentration plus one standard deviation

minimum measured concentration

maximum measured concentration



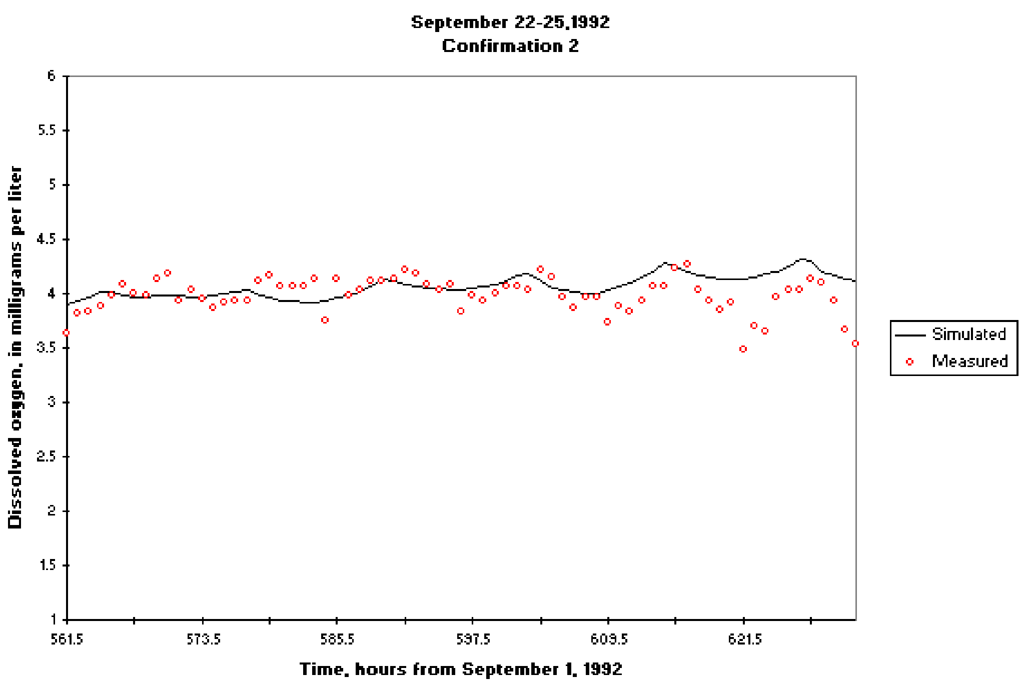
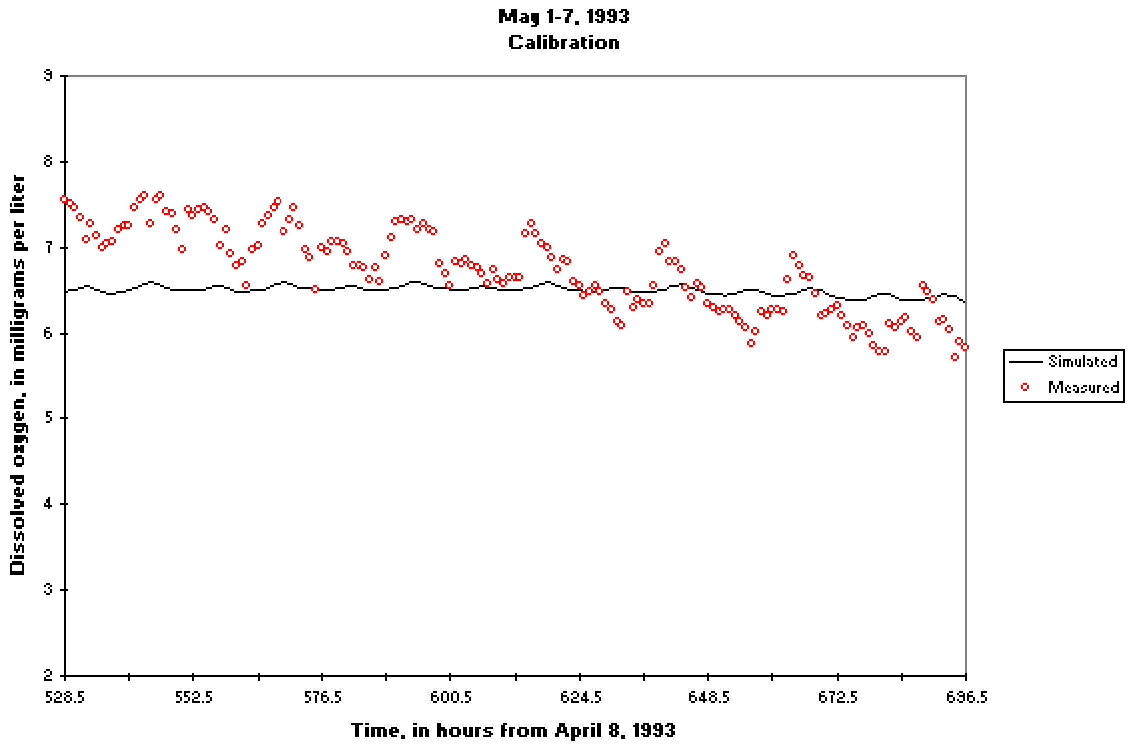


Figure 4. Comparison plots of recalibration for September 25, 1992 of dissolved oxygen time series at Station 021720869 (I-526) on the Ashley River. Figure based on figure 23 in WRRI 98-4150.



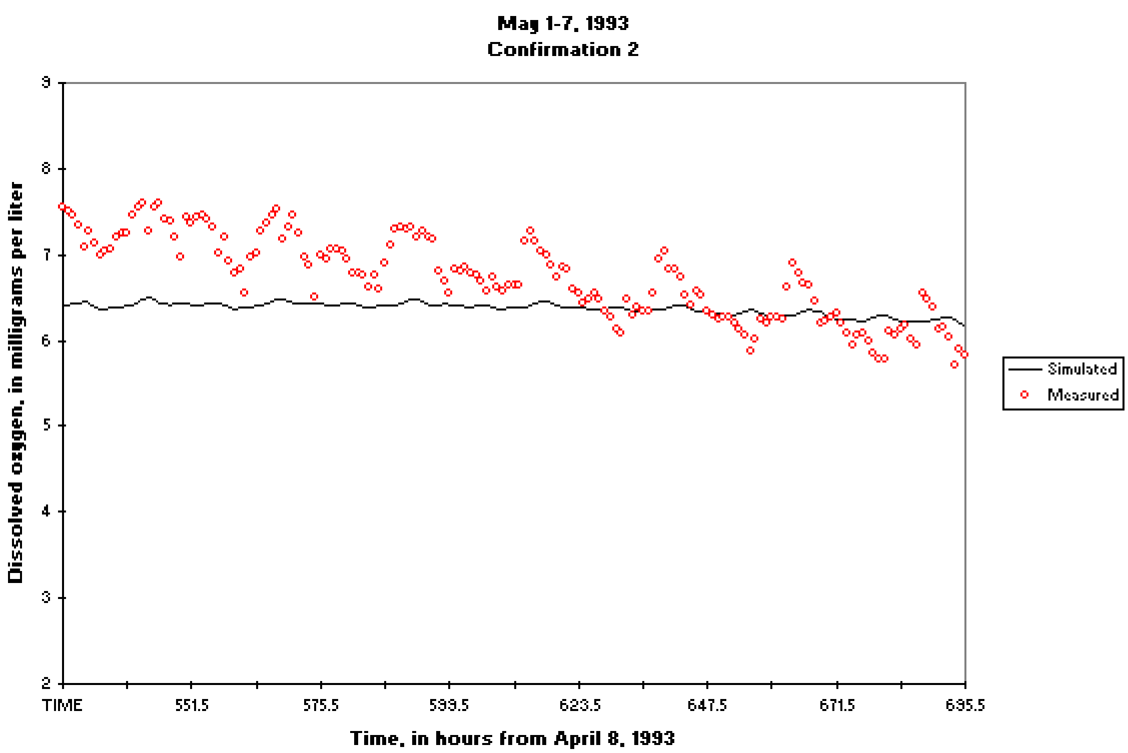
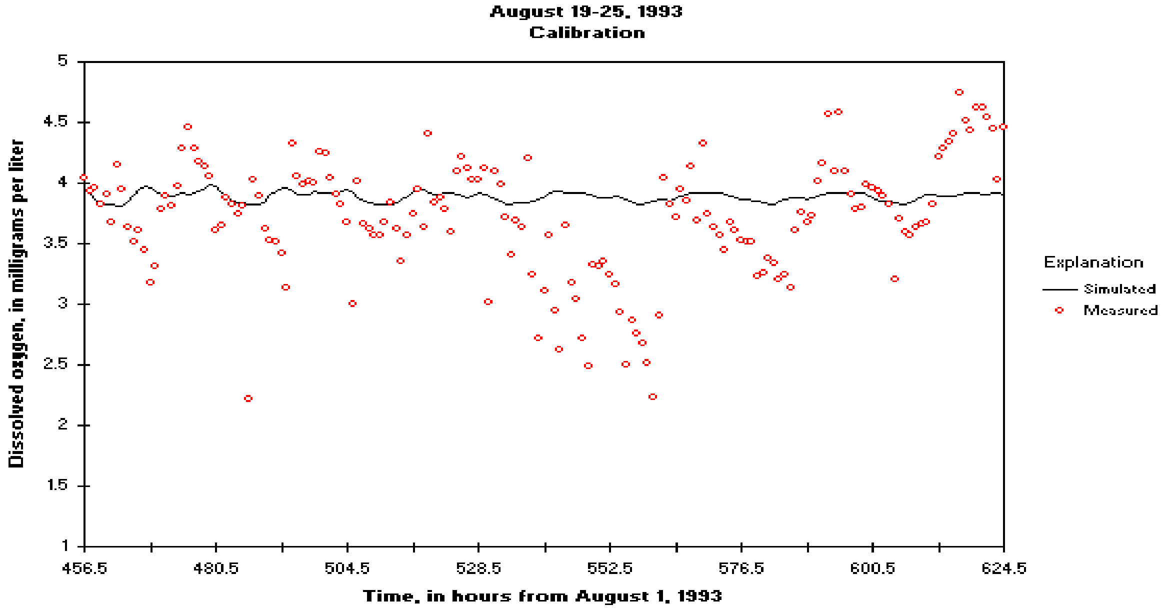


Figure 5. Comparison plots of dissolved-oxygen time series at Station 021720869 (I-526) on the Ashley River for May 1-7, 1993. Figure based on figure 23 in WRRI 98-4150.



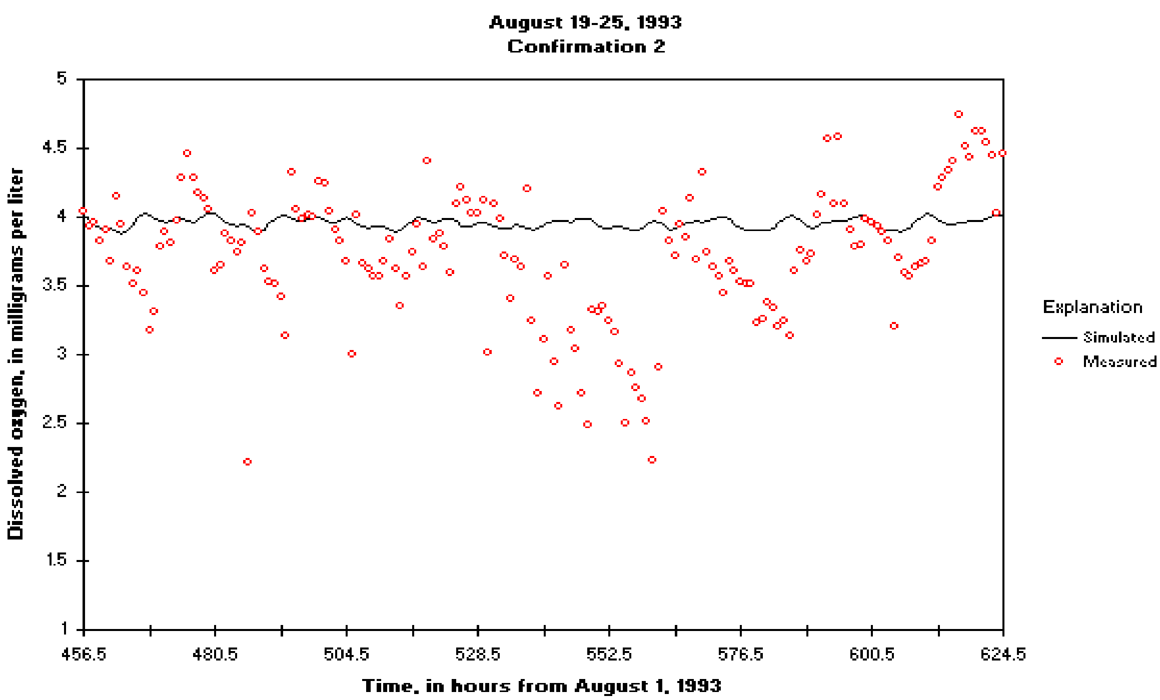


Figure 6. Comparison plots of recalibration, August 23-25, 1993, of dissolved-oxygen time series at Station 021720869 (I-526) on the Ashley River. Figure based on figure 23 in WRRI 98-4150.

`

APPENDIX C

TMDL Model Report

DEVELOPMENT OF THE CRITICAL CONDITIONS MODEL AND WASTELOAD ALLOCATIONS FOR THE ASHLEY RIVER TOTAL MAXIMUM DAILY LOAD

Wade M. Cantrell, South Carolina Department of Health and Environmental Control

August 2003

1. Introduction

This report documents the development of the critical conditions model used for the revised Ashley River Total Maximum Daily Load (TMDL) for oxygen demanding pollutants. It is prepared in advance of the formal TMDL report to allow for review of the modeling approach by the U.S. Environmental Protection Agency Region 4 (EPA) and will become part of the TMDL.

The original model calibration and validation are documented in Conrads (1998), the development of the first draft TMDL is documented in Sullins (2000), and the revised model calibration and validation are documented in Conrads (2003). The original model calibration and validation were revised by the U.S. Geological Survey (USGS) in response to public comments on the first draft TMDL and subsequent model review by USGS, EPA, and the S.C. Department of Health and Environmental Control (DHEC).

2. General Model Description

BRANCH/BLTM is a dynamic, one-dimensional, flow/water quality modeling platform capable of simulating reversing flows. The platform is appropriate for this application because the Ashley River experiences very little stratification for extended periods and the complex channel geometry of tidal marshes and old rice fields can be simplified in BRANCH as large storage areas that fill and drain with each tidal cycle (Conrads, 1998). The BLTM uses a Lagrangian reference frame in which the computational nodes move with the flow (Jobson and Schoellhamer, 1993).

The models and supporting programs for constructing input data and processing output data have been developed by USGS and are public domain software. BRANCH model documentation is found in Schaffranek et al. (1981). Updates to the original BRANCH code are found in USGS (1997). Version 4.2 (March 6, 1997) is used for this application. BLTM model documentation is found in Jobson and Schoellhamer (1993); updates are found in Jobson (1997). The version stamped December 4, 1997 is used here.

Supporting input data programs include the Time-Dependent Data System (TDDS) for managing the boundary value data used as input to BRANCH (Regan et al., 1996), CONPIPE for converting BRANCH output into BLTM input (BRANCH is set to a 15-minute time step while BLTM is set to a 60-minute time step), EQULTMP for estimating equilibrium water temperature (used by BLTM for water temperature simulation), and SOLAR for estimating incoming solar radiation (used by BLTM for algae simulation).

EQULTMP and SOLAR are described in Jobson (1997). BLTM output is processed using CTPLOT, which converts the time- and space-varying output data into time series concentrations at fixed locations.

3. Public Comments on the 12-2000 TMDL Model

The draft TMDL was placed on public notice on December 15, 2000. At the request of stakeholders, DHEC extended the deadline for comments from January 15 to January 31, 2001. At that time, DHEC received significant public comment on the proposed TMDL. A complete responsiveness summary will appear in the final TMDL report. Comments and responses related to technical aspects of the model are listed below.

1) Comment: The 1-dimensional BRANCH/BLTM models are not suitable for use in tidally influenced estuarine systems such as the Ashley River because they cannot capture the complex hydrodynamics of a multi-dimensional system, and they are not accurate enough to apply the Tenth Rule.

   Response: DHEC acknowledges that the 1-dimensional BRANCH/BLTM model may not be applicable to all estuaries. However, DHEC considers BRANCH/BLTM to be applicable to the Ashley River. The commenter is referred to the original USGS model report, Conrads (1998), which states BRANCH/BLTM is appropriate to apply to the Ashley River because there is little stratification for extended periods, and the complex geometry of tidal marshes and old rice fields can be simplified in BRANCH as large storage areas that fill and drain with each tidal cycle.

   DHEC acknowledges the model is not accurate enough to predict absolute DO concentrations to within 0.10 mg/L. However, we consider the model to be precise enough to predict changes in DO of 0.10 mg/L resulting from effluent loading. We note BRANCH/BLTM was successfully applied to the Waccamaw River and Atlantic Intracoastal Waterway to develop an approved TMDL under the Tenth Rule and believe the same approach is applicable to the Ashley River.

2) Comment: Simplifying assumptions used to represent the marsh areas in the model and in the grid configurations of the BRANCH and BLTM models necessitated post-processing of BRANCH output for use by the BLTM and call into question the accuracy of the model results. This resulted in the model's inability to accurately predict pollutant transport in the Upper Ashley River System.

   Response: All models contain simplifying assumptions. BRANCH and BLTM were successfully calibrated while representing the marshes as water storage areas (Conrads, 2003; Conrads, 1998). The representation of the marsh areas in the TMDL model is the same as the representation used in the calibrated model. DHEC concurs with USGS and EPA modelers that this representation is reasonable for the Ashley River model.

As stated in Conrads (2003), the model schematization was chosen to minimize numerical dispersion, i.e., to improve accuracy. The commenter is referred to Conrads (2003) for a detailed discussion. As with the representation of the marshes, the grid configuration used in the TMDL model is the same as the calibrated model.

3) Comment: The model calibration using salinity was improper because BLTM is a 1-dimensional model and cannot properly simulate the movement of salinity, and the model was artificially adjusted to force acceptable salinity comparisons. This resulted in unsatisfactory prediction of transport (i.e., flow) in the Upper Ashley River.

   Response: The model was calibrated to water level and flow in addition to salinity plus the eight state water quality parameters. Based on USGS, EPA, and DHEC model review, the predicted transport is considered acceptable.

4) Comment: It appears DHEC used higher background dissolved oxygen levels (4.11 to 5.12 mg/L) than those measured by USGS. Current data should be reviewed to verify this key model component.

   Response: Current data were reviewed and used to update background values for all constituents as described below in Section 4.4. The upper boundary DO concentration was set to 4.5 mg/L, the 25th percentile of measured data at USGS station 02172081 during July and August 2000-2001. The lower boundary was set to 4.81 mg/L, the 25th percentile for DHEC station MD-052 during July and August 1996-2001. These values were chosen as recommended by Butcher (1998) and are considered appropriate for this evaluation.

5) Comment: DHEC used an inappropriate nitrification rate. The combination of 1.0/day for ammonia to nitrite and 0.2/day for nitrite to nitrate used for the Ashley River is more than 30 times higher than the site-specific rate developed for the Savannah River. DHEC should document why such a high nitrification rate was used in light of the Savannah River rate, which we believe is equally applicable to the Ashley River.

   Response: The nitrification rate was reviewed and updated taking into account recent site-specific field data for the Ashley River. The current model uses 0.2/day for ammonia to nitrite and 0.4/day for nitrite to nitrate. The determination of these rate coefficients is described in Conrads (2003).

6) Comment: The light penetration coefficient is impossible.

Response: The comment appears to refer to the light extinction or light attenuation factor listed in Conrads (1998). USGS investigated this concern and determined the 0.1/m value listed in the report is a typographical error; the actual value that was used in the model is 0.7/m (Conrads, 2003). The current model, like the original model, uses the correct value of 0.7/m.

7) Comment: DHEC had insufficient data to properly develop a TMDL. This comment expressed concern that a significant portion of the data was only measured one time, was not corrected for wet and dry weather effects, was not corrected for other events (such as spring and neap tides), was outdated because it was collected before load reductions made during 1995, or was collected with no consistent data collection protocol.

   Response: The model is based on a significant data collection effort by USGS during 1992-1995 as part of the Charleston Harbor Project. USGS also reactivated sampling stations on the Ashley River in 2000. In addition, DHEC operates long-term monthly sampling stations throughout the Ashley River. Long-term meteorological data for Charleston Airport are collected by the National Weather Service and are readily available. This information represents a significant dataset that is suitable for TMDL development.

   The concern regarding the load reductions resulting from the Summerville WWTP upgrade in 1995 is valid. The current model has been updated to represent current conditions in the Ashley River. The commenter is referred to Conrads (2003) for information on updates to the model kinetics, including the nitrification rate, and to Section 4.4 of this report, which describes the data used to determine water quality boundary conditions.

8) Comment: It is unclear whether DHEC included the marsh exchanges in the model runs.

   Response: As noted above, the representation of the marsh areas used in the TMDL model is the same as the calibrated model.

9) Comment: DHEC could not document its verification of the no-load output under critical conditions.

   Response: No-load DO predicted by the current TMDL model was compared to available instream monitoring data, as recommended by EPA. Results are included as Attachment C. This comparison confirmed the TMDL model predictions are reasonable and consistent with conditions observed in the river.

10) Comment: The TMDL model was not properly documented.

Response: The current TMDL model is documented in this report. The model files will become part of the administrative record for this TMDL and will be provided upon request.

11) Comment: DHEC could not document model sensitivity or a proper uncertainty analysis.

    Response: The sensitivity of the impact (delta DO) predicted by the current TMDL model to critical condition inputs is discussed in Section 7 of this report.

12) Comment: DHEC appears to have consistently used the conservative end of literature values for the deoxygenation rate, the sediment oxygen demand, dissolved CBOD fraction, and organic matter settling rate. By doing this, DHEC has built into the models an excess of conservatism.

    Response: According to standard wasteload allocation modeling procedure, these inputs are set during the calibration process and are not changed in the critical conditions model used for TMDL development. USGS has evaluated and updated the model kinetic inputs as described in Conrads (2003). All kinetic inputs used in the current TMDL model are the same as those used by USGS in the calibration model.

13) Comment: The model cannot accurately predict dissolved oxygen changes as small as 0.1 mg/L.

    Response: The commenter is referred to the Response to Comment 1.

14) Comment: Effluent dissolved oxygen for Summerville should be verified.

    Response: The current TMDL model uses the existing permit limit for DO of 7 mg/L for the discharge by the Summerville WWTP.

15) Comment: DHEC's assertion that Applied Technology & Management, Inc. (ATM) confirmed the calibration of the model is not true.

    Response: DHEC retracts this assertion.

16) Comment: The proposed TMDL does not provide sufficient information regarding the low flow used in the TMDL analyses. In this location, which is both dam-controlled (the Cooper River) and tidal, the flow data used in the model must be made explicit, and the model must contain the most protective assumptions. *This comment appeared primarily directed at the Cooper River/Charleston Harbor TMDL. However, the comment was part of a single response to the draft TMDLs for both the Cooper River/Charleston Harbor and the Ashley River. The comment is equally applicable to both systems.*

Response: The low flow period used in the previous TMDL was evaluated and updated as appropriate. The commenter is referred to Sections 4.1, 7.1, 7.2, and 7.3 of this report.

17) Comment: DHEC should provide the reaction coefficients and clarify whether they are consistent with those used for the previous model calibration.

Response: DHEC confirms that the reaction coefficients used in the TMDL model are the same as those that were used for model calibration. The values used in both models appear in Conrads (2003).

4. Revised TMDL Model

In response to the comments, USGS, EPA and DHEC reviewed the model used to develop the draft TMDL. During the review, USGS made modifications to both the BRANCH flow model and the BLTM water quality model to address the comments and to enhance model performance. These modifications are described in Conrads (2003). USGS provided DHEC with updated model files, which were used to develop the critical conditions model for the TMDL. Except as described below, inputs for both BRANCH and BLTM TMDL simulations are the same as those in the revised calibrated model.

4.1. BRANCH Boundary Value Data

BRANCH boundary conditions were changed to represent critical conditions. The upstream boundary at Bacon Bridge was set to approximate 7Q10 conditions of freshwater inflow, and the seaward boundary near Charleston Harbor was selected to include both spring and neap tides, as recommended by Butcher (1998). The Butcher report is included as Attachment A.

The Ashley River is tidal with reversing flows throughout the model domain. USGS calibrated the model using measured water level data to drive both the upper and lower boundaries. The previous TMDL model developed by DHEC also used measured water levels; the period November 1-December 30, 1993 was selected from available data to represent critical conditions. During the review, it was determined the model-predicted net inflow at Bacon Bridge associated with this period is approximately 51 cfs. At the time of the first draft TMDL, the selection of the upper boundary flow may have been limited by the availability of suitable data.

Although measured flow data at the upper boundary are limited, the 7Q10 in Cypress Swamp at I-26 is reported to be zero (Bloxham, 1981). The Cypress Swamp site is located well upstream of the model boundary and so excludes a portion of the contributing drainage area; however, 7Q10 flows are reported to be zero or near zero throughout the Lower Coastal Plain for streams not fed by upland rivers, so little additional inflow would be expected during 7Q10 conditions. During extremely dry periods, with little freshwater draining from Cypress Swamp, saltwater extends through most of the Ashley River (Conrads, 1998). High specific conductance observed at Bacon Bridge during dry periods also supports using a boundary flow that is less than the 51 cfs used previously.

The net inflow at the upper boundary was reduced for the revised TMDL. To develop upper boundary data, DHEC requested that USGS use the observed water levels for the November 1-December 30, 1993 period and the BRANCH model to predict boundary flows. The flow data was stored in the database for use as boundary input to the model. USGS provided the appropriate model input files and guidance on their use. DHEC then adjusted the boundary flow input data using the flow multiplier in the BRANCH model until the net inflow at Bacon Bridge approximated 7Q10 conditions. The resulting net inflow to the TMDL model is approximately 5 cfs over the simulation period with the flow multiplier set to 0.1. This value was chosen to provide some positive forcing at the upper boundary while approaching 7Q10 conditions. The sensitivity of the predicted DO impact to the net inflow at the upper boundary is discussed in Section 7.1.

An alternative representation of the upper boundary was considered. During the review, USGS provided an alternative setup in which the upper boundary was set to a constant, or steady state, inflow. This setup was useful for testing the impact of different inflows. For the TMDL, the tidal boundary described above was used for consistency with the model calibration. The difference between the tidal and steady state upper boundary was not significant regarding the effect on the TMDL results (see Section 7.2).

Like the previous TMDL model, the revised TMDL model uses measured water levels from the November 1-December 30, 1993 period at the seaward boundary. This period included both spring and neap tides, as recommended by Butcher (1998). Other periods were tested, including synthetic water levels predicted by the WQMAP model used for the Cooper TMDL and provided by ATM. Results indicate the TMDL scenario was neither the most critical nor the least critical of the 15 periods tested. The percent difference in the predicted delta DO between the TMDL scenario and the most critical period was 13.0 percent in segment 1 and 14.1 percent in segment 2; the difference between the TMDL scenario and the least critical period was 2.8 percent in segment 1 and 13.0 percent in segment 2 (see Section 7.3).

In summary, the actual 7Q10 flow at the upper boundary has not been determined because this location is tidal with reversing flows and sufficient flow data are not available. The data that are available suggest very little inflow would be present under 7Q10 conditions. Based on the characteristics of the model, it is desirable to include some positive inflow at the upper boundary. The assumed value of 5 cfs satisfies both of these criteria. The tidal period used in the previous draft TMDL was shown to be intermediate compared to 14 additional periods tested and was retained in the current TMDL model. The critical flow conditions assumed in the current TMDL model are reasonable and suitably protective of water quality.

4.2. BRANCH Initial Conditions

Initial conditions for all TMDL simulations were developed using the first 8 days of the flow period to spin-up the BRANCH model. Output at the last time step of the 8-day spin-up runs was saved for initial conditions input to TMDL simulations. The resulting TMDL simulations were 51 days. Inspection of predicted flows confirmed the 8-day spin-up period was sufficient to eliminate the influence of the initial condition values on the TMDL simulation.

4.3. BRANCH Point Source Flows

As discussed in Conrads (2003), the revised model routes the pipe flows in BRANCH. Four WWTP discharges to the Ashley River are included in the TMDL: City of Summerville, King's Grant, Lower Dorchester County, and Middleton Inn. The model combines Summerville and King's Grant as one discharge and Dorchester County and Middleton Inn as a second discharge. Permitted flows were used for the TMDL model load run; flows were set to zero for the no-load run. Permitted flows used in the TMDL model are given in Table 1.

Table 1. Permitted Effluent Flows

Discharge	NPDES Permit No.	Permitted Flow (MGD)	Model Input	Combined Flow (MGD)
City of Summerville	SC0037541	10	Pipe 1	10.238
King's Grant	SC0021911	0.238		
Lower Dorchester County	SC0038822	4[1]	Pipe 2	4.014
Middleton Inn	SC0039063	0.014		

[1]Expansion to 8 MGD is planned.

Teal on the Ashley (NPDES Permit No. SC0030350) is located approximately four miles above the upper boundary of the model. A separate analysis was used to determine a wasteload allocation for this discharge (Sullins, 2000). Due its location and small loading, this discharge does not impact the BRANCH/BLTM model results. Charleston CPW Pierpont (NPDES Permit No. SC0026069) was inactivated in 2001 and is not included in the current model.

The Berkeley-Charleston-Dorchester Council of Governments (BCDCOG) is currently in the process of amending the tri-county plan to increase Dorchester County's flow from 4 to 8 MGD. Therefore, TMDL scenarios are developed for both the existing flow of 4 MGD and the expansion to 8 MGD.

4.4. BLTM Boundary Conditions

BLTM boundary conditions were determined using available monitoring data from the period 1996-2001. The period was chosen to represent conditions since the Summerville WWTP upgrade and subsequent load reduction. Data for July and August were combined, and 25th/75th percentiles were determined as recommended by Butcher (1998). Boundary conditions used in the TMDL are given in Table 2.

Table 2. TMDL Model Boundary Conditions

Boundary Condition	Upper Boundary Value	Source	Lower Boundary Value	Source
Temperature (°C)	28.5	Station 02172081 75th percentile, published data (N=124)	28	Cooper/Wando/Charleston Harbor TMDL Model
Algal Biomass (mg/L)	0	(Butcher, 1998)	0	(Butcher, 1998)
NH3 (mg N/L)	0.17	Station CSTL-102 75th percentile (N=11)	0.32	Station MD-052 75th percentile (N=9)
NO2 (mg N/L)	0	see NO3	0	see NO3
NO3 (mg N/L)	0.13	Station CSTL-102 75th percentile NO2+NO3, assumed all NO3 (N=12)	0.13	Station MD-052 75th percentile NO2+NO3, assumed all NO3 (N=12)
Dissolved P (mg P/L)	0.22	see organic P	0.06	see organic P
CBODu (mg/L)	5.9	Station CSTL-102 75th percentile BOD5 multiplied by assumed F-Ratio=1.5 (N=11)	3.2	Station MD-052 75th percentile BOD5 multiplied by assumed F-Ratio=1.5 (N=12)
DO (mg/L)	4.5	Station 02172081 25th percentile, published data (N=124)	4.81	Station MD-052 25th percentile (N=12)
Organic N (mg N/L)	1.36	Station CSTL-102 75th percentile of measured TKN-NH3 (N=10)	0.59	Station MD-052 75th percentile of measured TKN-NH3 (N=8)
Organic P (mg P/L)	0.07	Station CSTL-102 75th percentile total P split into dissolved P and organic P using ratio from model calibration (N=3)	0.04	Station MD-052 75th percentile total P split into dissolved P and organic P using ratio from model calibration (N=4)

4.5. BLTM Meteorological Data

Meteorological data at Charleston Airport were obtained from the Southeast Regional Climate Center. The 75th percentile daily minimum and maximum air temperatures during 1992-2001 for combined July and August data were 75 and 93 °F, respectively. The 25th percentile wind speed during July and August for 1999-2001 was 4.6 mph. These values were used as inputs to EQULTMP to generate the equilibrium water temperature and wind speed data used by BLTM for water temperature simulation.

4.6. BLTM Initial Conditions

Boundary conditions were used for the initial conditions in BLTM. Upper boundary conditions were used for initial conditions in branch 1, grids 1-9, and lower boundary conditions were used in branch 2, grids 1-9.

4.7. BLTM Point Source Concentrations

Point source concentrations were determined for each scenario using an effluent flow-weighted average. As noted above, model Pipe 1 represents Summerville and King's Grant and model Pipe 2 represents Dorchester and Middleton Inn. Inputs for CBODu, NH3, Organic N, and DO were adjusted for TMDL development. Other parameters were set equal to upper boundary concentrations.

CBODu was calculated assuming an F-ratio (CBODu/CBOD5) of 1.5 for all discharges as specified in the DHEC/EPA Agreement regarding wasteload allocation modeling (DHEC/EPA, 1991). Discussions with USGS staff indicated this F-ratio was also used in model calibration. Note the actual F-ratio may be higher at the proposed TMDL treatment levels, and the actual value should be determined if future modeling is conducted.

Organic N was assumed to be one half of the NH3 concentration (DHEC/EPA, 1991). DO was set to existing permit limits except for Middleton Inn, which has a limit of 2 mg/L but was set to 5 mg/L for the TMDL scenarios.

Due to the different kinetic characteristics of CBODu and NH3 in the model as well as the different unit consumption of oxygen by these constituents, the allowable UOD depends on the relative concentrations of CBODu and NH3 in the effluent.

5. TMDL Target

The classification and DO Standard for the Ashley River are given in Table 3 (S.C. Regulation 61-68 and R.61-69).

Table 3. Ashley River Classification and DO Standard

Segment	Classification	DO Standard
Above Bacon Bridge	FW	daily average of 5.0 mg/L with a low of 4.0 mg/L
Bacon Bridge to Church Creek	SA	daily average of 5.0 mg/L with a low of 4.0 mg/L
Church Creek to Orangegrove Creek	SA*	site specific, not less than 4.0 mg/L
Orancegrove Creek to Charleston Harbor	SA	daily average of 5.0 mg/L with a low of 4.0 mg/L

DHEC collects monitoring data at two locations on the upper Ashley River: station CSTL-102, Ashley River at Bacon Bridge, and station MD-049, Ashley River at Magnolia Gardens. Station CSTL-102 is approximately three miles above the Summerville WWTP discharge, and station MD-049 is approximately five miles below the Dorchester County WWTP discharge. Both stations are listed as impaired due to low DO on the S.C. 303(d) List for 2002. As noted above, USGS station 02172081, Ashley River at Cooke Crossroads (Bacon Bridge) was used to determine the DO boundary condition for the TMDL model. The 25th percentile daily average value was 4.5 mg/L based on published data for July and August, 2000-2001. Provisional USGS daily average data for 2002-2003 show significant periods during summer and fall when DO levels are well below the numeric standard from Cypress Swamp to Bakers Landing (USGS, 2003). Based on this information, the upper Ashley River fails to meet the numeric standard for DO.

DHEC considers these periods to be naturally occurring phenomena exacerbated by point and non-point sources. Consequently, Regulation 61-68, Section D.4 and the S.C. Pollution Control Act, Section 48-1-83 require that the cumulative impact resulting from point sources and other activities be no more than 0.10 mg/L, as a daily average, unless a site specific standard is determined according to procedures given in DHEC (1999). At the time of the first draft TMDL, comments received by DHEC expressed interest in pursuing a site-specific standard, and stakeholders public noticed their intent to seek a site-specific standard. However, a site-specific standard has not been developed, and DHEC has no knowledge of any further action to conduct the necessary biological and water quality studies and analyses to determine a standard. Therefore, the target for this TMDL is a maximum daily average DO impact of 0.10 mg/L.

The current BRANCH/BLTM model application to the Ashley River is appropriate for evaluating point source waste loads under dry weather conditions. The impact of non-point source loads is not addressed in the current model.

The approach used to apply the allowable impact in the recently approved Cooper TMDL was based on dividing the system into segments with similar chemical and physical characteristics and calculating a volume-weighted daily average delta DO for each segment (Greenfield, 2002). The critical segments were the lower Cooper River from Goose Creek to the mouth (river mile 6.3 to 13.7) and the Cooper/Wando estuary (river mile 4.2 to 6.3). A similar approach is recommended for the Ashley River TMDL. The analysis used to determine the segments appears in Attachment B. The analysis resulted in an upper Segment 1 for Pipe 1 (Summerville and King's Grant) and a lower Segment 2 for Pipe 2 (Dorchester and Middleton Inn), as indicated in Table 4. Note the segmentation is based on the assumed upper boundary inflow of 5 cfs.

Table 4. TMDL Segments

Segment	River Reach (miles below Bacon Bridge)	Pipe	Pipe Location (miles below Bacon Bridge)	Discharge Name	NPDES Permit No.
1	2-7	1	4.0	City of Summerville	SC0037541
				King's Grant	SC0021911
2	7-12	2	9.4	Lower Dorchester County	SC0038822
				Middleton Inn	SC0039063

BLTM output was processed using CTPLOT to get time series DO concentrations at 0.5-mile intervals in Segment 1 and 1.0-mile intervals in Segment 2. The interval was limited by the maximum number of output locations allowed in CTPLOT, but, in any case, the intervals are appropriate based on the longitudinal gradients predicted in the two segments. A spreadsheet program was used to compute the average impact in each segment. The spreadsheet imports the predicted flow file containing cross section areas, the predicted no-load DO file, and the predicted load DO file and calculates the maximum volume-weighted daily average delta DO (no-load DO minus load DO) in each segment over the simulation period. TMDL loads are acceptable when the predicted delta DO is less than or equal to 0.10 mg/L in both segments.

6. TMDL Model Scenarios

A no-load scenario was used as the baseline condition against which impacts were determined. The no-load run inputs are identical to the load runs except pipe flows and loads were set to zero. Predicted no-load DO was compared to available instream monitoring data, as recommended by EPA. This comparison confirmed the TMDL model predictions are reasonable and consistent with conditions observed in the river, as shown in Attachment C.

Several load scenarios were evaluated for TMDL development. Effluent concentrations were adjusted from the existing permit limits shown in Table 5. Allowable concentrations were determined for both 4 MGD and 8 MGD by Dorchester County. The model scenarios are given in Table 6.

Table 5. Existing Monthly Average Permit Limits

Model Pipe	NPDES	Name	Flow (MGD)	BOD_5 (mg/L)	NH_3-N (mg/L)	DO (mg/L)	UOD[1] limit (#/day)	UOD[1] calculated (#/day)
1	SC0037541	CPW/City of Summerville	10	12.5[2]	2	7	1601	NA
	SC0021911	CWS/Kings Grant on the Ashley	0.238	30	NL[3]	5	NL	271
2	SC0039063	Middleton Inn	0.014	30	NL[3]	2	NL	16
	SC0038822	Dorchester CPW/Lower Dorchester WWTP	4	15	1	5	NL	903

NA=not applicable; NL=no limit

[1]Assumed F-Ratio = 1.5

[2]Summerville is $CBOD_5$

[3]20 mg/L assumed

Table 6. TMDL Model Scenarios

No.	Scenario	Pipe	Flow (MGD)	$CBOD_5$[1] (mg/L)	NH_3-N (mg/L)	DO (mg/L)	UOD Pipe 1 / Pipe 2 (lbs/day)	delta DO Seg 1 / Seg 2 (mg/L)
1	12-2000 TMDL	1	10.238	3.03	0.57	5	610 / 280	**0.06 / 0.01**
		2	4.014	3.54	0.67	5		
2	Existing Permit	1	10.238	10.22	1.44	7	1872 / 919	**0.52 / 0.14**
		2	4.014	15.05	1.07	5		
3	Pipe 1 Permit	1	10.238	10.22	1.44	7	1872 / 328	**0.51 / 0.06**
	Pipe 2 Reuse	2	4.014	5	0.5	6		
4	Equal Treatment	1	10.238	5	0.807	7	955 / 375	**0.10 / 0.03**
		2	4.014	5	0.807	6		
5	TMDL-Existing Flows	1	10.238	5	0.807	7	955 / 826	**0.10 / 0.08**
		2	4.014	14	0.807	5		
6	TMDL-Dorchester at 8 MGD	1	10.238	5	0.807	7	955 / 948	**0.10 / 0.08**
		2	8.014	7	0.807	5		

[1]Five-day CBOD is shown; actual model input is ultimate CBOD, determined as $CBOD_u$ = F-Ratio*$CBOD_5$, where the assumed F-Ratio=1.5.

Scenario 1 used the loads from the first draft TMDL dated 12-2000. The impact is less than the allowable impact of 0.10 mg/L using the revised TMDL model, indicating additional assimilative capacity (greater allowable loading) than was predicted with the original TMDL model. The difference is due to (1) revisions in the model calibration described in Conrads (2003), which include routing of pipe flows and adjustment of model kinetics, (2) revisions to TMDL model inputs, as described above, and (3), perhaps most significantly, a revised approach for evaluating the target impact, i.e., changing from evaluating the impact at a point to using a volume-weighted average over a river segment.

Scenario 2 used existing permit loads. Predicted impacts exceeded the target in both segments. In Scenario 3, Pipe 1 was held at permit limits, and Pipe 2 was reduced to reuse limits (5 mg/L BOD5, 0.5 mg N/L NH_3, and 6 mg/L DO) to test the influence of Pipe 2 on the predicted impact in Segment 1. Results indicate Pipe 1 controls the impact in Segment 1. In Scenario 4, both pipes were adjusted until equal effluent CBODu and NH_3 concentrations met the target in Segment 1, after rounding up to 0.10 mg/L. Then, in Scenario 5, Pipe 2 CBODu was increased to the maximum level without ticking up to 0.11 mg/L in Segment 1, while the Pipe 1 loading remained constant at Scenario 4 levels. Scenario 5 is predicted to meet the water quality target in both segments.

In Scenario 6, Pipe 2 flow was increased to 8.014 MGD to represent the planned 8-MGD expansion by Dorchester County. Pipe 2 CBODu was reduced until the standard was met in both model segments.

Wasteload allocations and TMDLs often give the maximum allowable Ultimate Oxygen Demand (UOD) in lbs/day, defined as:

$$UOD = 8.34*Flow*(F\text{-}Ratio*(BOD5 \text{ or } CBOD5) + 4.57*NH3),$$

where:

UOD is lbs/day;
8.34 is a units conversion factor;
Flow = effluent flow in MGD;
F-Ratio = ratio of CBODu/BOD5 = 1.5;
BOD5 is mg/L;
4.57 = units of DO consumed per unit of NH_3;
NH_3 is mg N/L.

In this case, the effluent flow is significant compared to the net flow in the river at TMDL conditions, and the model decay rate is higher for NH_3 than for CBOD. Model results show allowable UOD depends on (1) effluent flow, (2) effluent mix of CBOD and NH_3, and (3) effluent DO. Consequently, concentration limits for BOD5 (or CBOD5), NH_3, and DO are required to limit the predicted impact to 0.10 mg/L. The calculated UOD mass loading is provided for information.

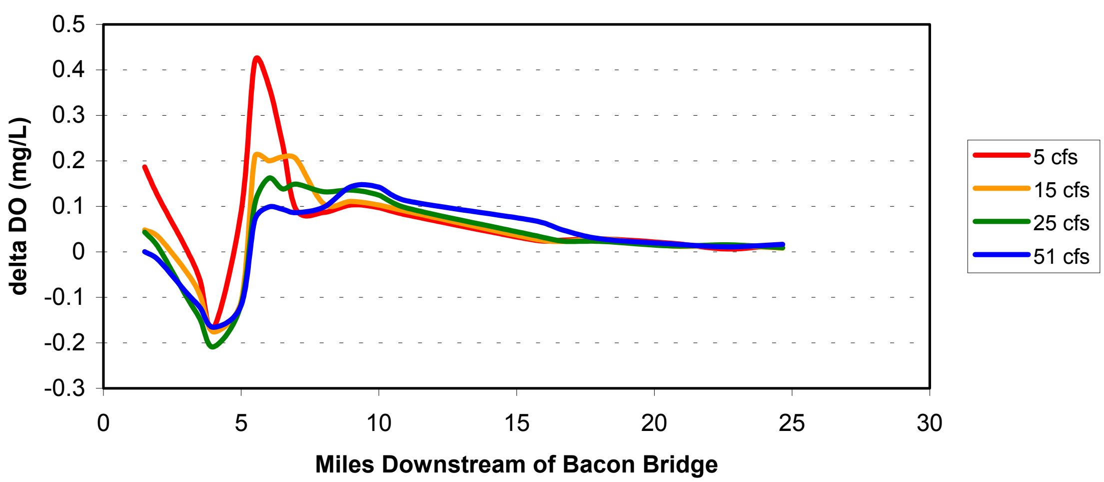
7. TMDL Model Sensitivity

A sensitivity analysis was performed on the critical conditions inputs used in the TMDL model. Model inputs not included in this analysis, e.g., reaction kinetics, were set during the calibration process. Results are discussed below.

7.1 Upper Boundary Inflow

As discussed in Section 4.1, the BRANCH flow multiplier was used to set the upper boundary flow to critical conditions for the TMDL model. A value of 0.1 was used to achieve a net inflow of approximately 5 cfs during the simulation period. The sensitivity of the predicted DO impact to the net inflow was tested by adjusting the multiplier to 0.3, 0.5, and 1.0, thereby increasing the net inflow to approximately 15, 25, and 51 cfs, respectively. Discharges were held at TMDL loads (Table 6, No. 5). Predicted impacts under the four inflow conditions are compared in Figure 1. Longitudinal profiles were used instead of the segment-averaged delta DO since the segments are based on 5 cfs inflow. Note the longitudinal profiles show the maximum daily average delta DO predicted during the simulation period rather than the delta DO at any one time. Negative values result from the net addition of oxygen by Summerville WWTP in the load scenario and the absence of this DO input in the no-load scenario. Results show the delta DO is sensitive to the net inflow at the upper boundary.

Figure 1. delta DO Response to Varying Upper Boundary Inflow



7.2 Upper Boundary—Tidal vs. Steady State

As discussed in Section 4.1, the flow model was calibrated using measured water levels at the upper boundary at Bacon Bridge. The TMDL model uses simulated flows determined previously by running the BRANCH model with measured water levels for the period November 1-December 30, 1993. As described above, the flow data were adjusted to represent critical conditions of a net inflow of 5 cfs while allowing tidally reversing flows. This setup was compared to an alternative representation of a constant 5 cfs inflow. In terms of impact on instream DO, the two setups were not significantly different, as indicated in Table 7. The tidal upper boundary was chosen for consistency with model calibration.

Table 7. Upper Boundary—Tidal vs. Steady State Sensitivity Results

Run	Upper Boundary	Lower Boundary	Segment 1 delta DO (mg/L)	Segment 2 delta DO (mg/L)
1*	tidal 5 cfs net	11/10/93-12/30/93	0.1048	0.0825
2	steady state 5cfs	11/10/93-12/30/93	0.1047	0.0815

*TMDL scenario

7.3 Lower Boundary—Critical Flow Period

The flow period used in the TMDL model was compared to 14 additional periods for which data were available, including a synthetic flow period developed by ATM from the WQMAP model used for the Cooper TMDL. Results are given in Table 8. The November 1-December 30, 1993 period used in the previous draft TMDL modeling was found to be intermediate in terms of DO impact and was retained in the current TMDL model.

Table 8. Lower Boundary—Critical Flow Period Sensitivity Results

Run	Upper Boundary	Lower Boundary	Segment 1 delta DO (mg/L)	Segment 2 delta DO (mg/L)
1*	**tidal 5 cfs net**	**11/10/93-12/30/93**	**0.1048**	**0.0825**
2	steady state 5cfs	synthetic	0.1171	0.0889
3	steady state 5cfs	7/11/92-8/30/92	0.1173	0.0824
4	steady state 5cfs	8/31/92-10/20/92	0.1183	0.0718
5	steady state 5cfs	10/21/92-12/10/92	0.1053	0.0866
6	steady state 5cfs	12/11/92-1/30/93	0.1135	0.0887
7	steady state 5cfs	1/31/93-3/22/93	0.1183	0.0902
8	steady state 5cfs	3/23/93-5/12/93	0.1175	0.0941
9	steady state 5cfs	5/13/93-7/2/93	0.1075	0.0873
10	steady state 5cfs	7/3/93-8/22/93	0.1184	0.0858
11	steady state 5cfs	10/10/93-11/29/93	0.1168	0.0757
12	steady state 5cfs	11/30/93-1/19/94	0.1019	0.0926
13	steady state 5cfs	1/20/94-3/11/94	0.1042	0.0870
14	steady state 5cfs	3/12/94-5/1/94	0.1030	0.0861
15	steady state 5cfs	5/2/94-6/21/94	0.1044	0.0721

*TMDL scenario

High - TMDL	0.0136	0.0116
Percent Difference	13.0	14.1
TMDL - Low	0.0029	0.0107
Percent Difference	2.8	13.0

7.4 Water Quality Boundary Conditions

The sensitivity of the delta DO to boundary concentrations for the eight water quality constituents was tested (algae was not simulated in the TMDL model; temperature is discussed below). Results appear in Table 9. Results indicate no effect of changing boundary NO3, dissolved P, or organic P, as expected since the algae are turned off. Predicted DO impact decreased with increased boundary CBODu and organic N, consistent with a reduction in the relative impact of effluent CBODu and organic N when background levels increase. Predicted DO impact increased when boundary NO2 was increased. This appears to be due to the assumption that effluent NO2 is equal to boundary NO2; under this assumption, effluent NO2 and the demand associated with NO2 increase when boundary NO2 is increased. Predicted DO impact was relatively insensitive to changes in boundary DO and NH3.

Table 9. Water Quality Boundary Conditions Sensitivity Results

Input	Base Value	Test Value	Percent Change	Segment 1 delta DO (mg/L)	Segment 2 delta DO (mg/L)	Segment 1 Percent Change	Segment 2 Percent Change
Base Run	--	--	--	0.1048	0.0825	--	--
NH3 (mg N/L)	0.17/0.32	0.21/0.40	+25	0.1046	0.0823	-0.2	-0.2
NO2 (mg N/L)	0/0	0.2/0.2	--	0.1185	0.0840	+13.1	+1.8
NO3 (mg N/L)	0.13/0.13	0.16/0.16	+25	0.1048	0.0825	0	0
dissolved P (mg P/L)	0.22/0.06	0.28/0.08	+25	0.1048	0.0825	0	0
CBODu (mg/L)	5.9/3.2	7.38/4.0	+25	0.0863	0.0787	-17.7	-4.6
DO (mg/L)	4.5/4.81	5.63/6.01	+25	0.1023	0.0830	-2.4	+0.6
organic N (mg N/L)	1.36/0.59	1.7/0.74	+25	0.0844	0.0783	-19.5	-5.1
organic P (mg P/L)	0.07/0.04	0.09/0.05	+25	0.1048	0.0825	0	0

7.5 Temperature and Meteorological Inputs

In the TMDL model, upper boundary temperature is set to the 75th percentile of measured data for July and August, 28.5 °C. The lower boundary is set to the temperature used in the Cooper TMDL model, 28 °C, also the 75th percentile. Effluent temperature was assumed equal to the upper boundary temperature. Equilibrium water temperature data were developed using the 75th percentile of measured daily max/min air temperature for July and August, 93/75 °C. Wind speed was set to the 25th percentile of measured data for July and August, 4.6 mph. These conditions result in a simulated instream temperature of approximately 29 °C in the TMDL model.

Two additional temperature regimes were developed by adjusting boundary, effluent, and equilibrium temperatures. Boundary DO was adjusted to the same percent saturation used in the TMDL model. Instream temperature was approximately 33 °C in the "high" temperature scenario and 19 °C in the "low" temperature scenario. Predicted impact for each scenario is compared in Table 10.

Table 10. Instream Temperature Sensitivity Results

Temperature Scenario	Instream Temperature (°C)	Segment 1 delta DO (mg/L)	Segment 2 delta DO (mg/L)
High	33	0.02	0.06
TMDL	29	0.10	0.08
Low	19	0.32	0.12
High*	33	0.22	0.07
TMDL*	29	0.28	0.08
Low*	19	0.32	0.10

*effluent DO set to background level

Predicted impact of TMDL loads was inversely related to temperature. The primary cause is the net difference between instream DO and effluent DO, particularly in the upstream segment. As noted in Section 6, predicted impact and allowable loading of oxygen demand are dependent on effluent DO levels. In the TMDL scenario, no-load DO at Pipe 1 averages 4.3 mg/L while Pipe 1 DO is 6.95 mg/L, so the effluent DO elevates instream DO in the load run compared to the no-load run and thereby mitigates some of the predicted impact. In the high temperature scenario, no-load DO at Pipe 1 averages 3.3 mg/L, so the net addition of DO to the river by the effluent is greater than in the TMDL scenario, and the impact, as defined, is less. No-load DO in the low temperature scenario averages 7 mg/L, so the opposite occurs. This effect is present but less important at Pipe 2 due to lower permitted effluent flow, lower permitted DO, and higher dilution.

The three scenarios were rerun with effluent DO set to instream no-load DO. Results indicate effluent DO is the primary cause, but other factors contribute to the inverse relationship between temperature and predicted impact. Model source and decay terms for oxygen demanding constituents respond differently to temperature changes due to different temperature correction factors, and the kinetics were calibrated under summer conditions. The predictions of any model are expected to be less reliable under conditions that differ significantly from calibration conditions. In this case, altering model temperature to temperatures outside of the calibration temperature gave results that are counter to conventional wisdom, which holds that impact and temperature are positively related.

Increasing wind speed by 25 percent resulted in a slight increase in the predicted impact in the upstream segment, as shown in Table 11. The impact is not sensitive to wind speed because wind speed does not influence model reaeration since reaeration rates are specified as model inputs and not calculated internally.

Table 11. Wind speed Sensitivity Results

Input	Base Value	Test Value	Percent Change	Segment 1 delta DO (mg/L)	Segment 2 delta DO (mg/L)	Segment 1 Percent Change	Segment 2 Percent Change
Base Run	--	--	--	0.1048	0.0825	--	--
wind speed (mph)	4.6	5.75	+25	0.1051	0.0825	+0.3	0

8. References

Bloxham, W.M, 1981. Low-flow characteristics of ungaged streams in the Piedmont and Lower Coastal Plain of South Carolina. S.C. Water Resources Commission Report No. 14. 48 pp.

Butcher, J.B., 1998. Review of South Carolina modeling applications for dissolved oxygen. Report prepared by Tetra Tech, Inc. for EPA. May 6, 1998. 13 pp.

Conrads, P.A., 2003. Enhancements to the BRANCH model and re-calibration of the BLTM model of the Ashley River. Report prepared for EPA Region 4. July 22, 2003. 27 pp.

Conrads, P.A., 1998. Simulation of temperature, nutrients, biochemical oxygen demand, and dissolved oxygen in the Ashley River near Charleston, South Carolina. USGS Water-Resources Investigations Report 98-4150. 56 pp.

Greenfield, J.M., 2002. Charleston Harbor TMDL model review, Ashley Cooper river system, final review package. May 2, 2002. 23 pp.

Jobson, H.E., 1997. Enhancements to the Branched Lagrangian Transport Modeling System. USGS Water-Resources Investigations Report 97-4050. 57 pp.

Jobson, H.E. and D.H. Schoellhamer, 1993. Users manual for a Branched Lagrangian Transport Model. USGS Water-Resources Investigations Report 87-4163, revised 1993. 80 pp.

Regan, R.S., R.W. Schaffranek, and R.A. Baltzer, 1996. Time-Dependent Data System (TDDS)--An interactive program to assemble, manage, and appraise input data and numerical output of flow/transport simulation models. USGS Water-Resources Investigations Report 96-4143. 104 pp.

Schaffranek, R.W., R.A. Baltzer, and D.E. Goldberg, 1981. A model for simulation of flow in singular and interconnected channels. Techniques of Water-Resources Investigations of the United States Geological Survey, Book 7, Chapter C3. 110 pp.

State/EPA Region 4, 1991. Agreement on the development of wasteload allocations/total maximum daily loads and NPDES permit limitations. October 30, 1991. 31 pp.

Sullins, N.R., 2000. Total Maximum Daily Load (TMDL), Ashley River, South Carolina. December 4, 2000.

USGS, 2003. Provisional water quality data available at http://sc.water.usgs.gov/water-data.html.

USGS, 1997. Summary of enhancements and additions to the Branch-Network (BRANCH) Dynamic Flow Model. March 11, 1997. 39 pp.

Attachment A: Butcher Report

TETRA TECH, INC.
10306 Eaton Pl Suite 340
Fairfax, VA 22030
Telephone (703) 385-6000

RECEIVED

MAY 11 1998

BUREAU OF WATER
WATER QUALITY DIVISION

May 6, 1998

Mr. Chris Laabs
U.S. EPA
499 South Capital Street
Washington, D.C. 20024

Dear Chris:

Enclosed is the revised response to the South Carolina TMDL SWAT request. The revision was based on comments received from EPA and South Carolina Department of Health and Environmental Control staffs. If you have questions about the content of this report, please feel free to call me at (703) 385-6000. Thanks.

Sincerely,

John P. Craig
Environmental Scientist

cc: Jim Greenfield, EPA Region 4
Larry Turner, SC DHEC

Review of South Carolina Dynamic Modeling Applications for Dissolved Oxygen

Jonathan B. Butcher, Ph.D., P.H.
Tetra Tech, Inc.
May 6, 1998

1. Summary

Through the EPA SWAT program, the South Carolina Department of Health and Environmental Control (DHEC) requested a review of their application of dynamic modeling to wasteload allocation development for biochemical oxygen demand (BOD) and ammonia loading in terms of their impacts on dissolved oxygen (DO). This report is based on a review of two draft wasteload allocation model applications to the Waccamaw River/Intracoastal Waterway system and to the Cooper/Wando River system.

DHEC specifically requested an assessment of (1) the appropriateness of using dynamic models to determine wasteload allocations, (2) the methodology used to determine critical conditions, (3) the averaging period used to evaluate model output for compliance with standards, and (4) the methodology used to determine permit limits from model output. In general these applications are of high quality and relevant to establishing appropriate wasteload allocations. The following summarizes the results of the review:

- Dynamic models of the type used by DHEC are appropriate for wasteload allocations in tidal systems.

- Critical conditions used in the existing wasteload allocation applications might be overly stringent. Additional analysis of critical conditions for determination of wasteload allocations might hold excursions of the DO standard to an acceptably low frequency.

- Consideration might be given to the use of a fixed daily period (rather than running a twenty-four hour average) for evaluation of the daily average instead of 7-day average concentrations. In addition, evaluation of dynamic model output both in terms of instantaneous concentrations (for compliance with the instantaneous DO standard) and daily average concentrations (for compliance with the daily average standard) would coordinate with the state water quality standards.

- A statistical method can be used to evaluate the consistency of permit limits with the wasteload allocations.

2. Relevant Standards

In wasteload allocations, models are applied to determine and predict attainment of water quality standards. Therefore, appropriate model application and interpretation of model output is consistent with the applicable state standards. South Carolina standards are summarized in this section.

DO Standards

Dynamic models of the DO balance are proposed by DHEC for analysis of waterbodies in which steady state and tidally averaged models may lead to an incomplete or incorrect evaluation of the impacts of loads of oxygen demanding waste. This includes estuarine and tidally-influenced freshwater rivers, as well as rivers controlled by hydroelectric power plants. The most relevant South Carolina water use classifications in which dynamic models are likely to be applied for wasteload allocations are Freshwaters ("freshwaters suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment..."), Class SA ("tidal saltwaters suitable for primary and secondary contact recreation"), and Class SB ("tidal saltwaters suitable for primary and secondary contact recreation, crabbing and fishing, except harvesting of clams, mussels, or oysters for market purposes or human consumption"). Within Freshwaters and Class SA waters, the following quality standard is established for DO: "Daily average not less than 5.0 mg/l with a low of 4.0 mg/l." Within Class SB waters the standard for DO oxygen is "not less than 4.0 mg/l."

Applicability of Standards

These standards are not applied under extreme low flow conditions. The general statement on applicability at C(2)(a) and (b) states:

> (a) With the exception of human health criteria...the numeric standards...are applicable to any flowing waters when the flow rate is equal to or greater than the minimum seven day average flow rate that occurs with an average frequency of once in ten years (7Q10).
> (b) The Department will consider flows other than 7Q10 where appropriate to protect classified and existing uses.

In addition, South Carolina's antidegradation statement at D(4) provides for water bodies in which the DO concentration will naturally contravene the standards (the "point one" rule):

> Under certain conditions, the quality of some free flowing surface waters and lakes... does not meet numeric standards for dissolved oxygen due to natural conditions, even though classified uses in these waters are achieved. Under these conditions, the quality of the free flowing surface waters or lakes...shall not be cumulatively lowered more than 0.10

mg/l for dissolved oxygen from impacts by point sources and other activities, unless a site-specific standard is established.

Comments

The regulations state that 4 mg/l is an instantaneous minimum standard for DO and the 5 mg/l standard (applicable to Freshwaters and Class SA waters) is defined as a daily average.

The applicability statement recognizes that appropriate DO standards are likely to be contravened under rare conditions of extreme low dilution. The intent of the standard is not to ensure that instantaneous DO concentrations less than 4 mg/l (and daily average concentrations less than 5 mg/l) *never* occur; rather, it is to ensure that excursions of the standard are held to an acceptably low frequency. In flowing streams this goal is achieved by specifying that the standards are applicable only when flow is equal to or greater than the 7Q10 flow; it is expected that a low (but non-zero) frequency of excursions will occur during those infrequent time periods when flow is less than 7Q10.

The 7Q10 flow is established as a cutoff value of flow rate for applicability of the standards. Even though this flow rate is estimated as a 7-day average, no averaging period for applicability of the standard is necessarily implied by use of the 7Q10 calculation. For instance, analysis of historical flow records might establish that the 7Q10 flow for a given river is 100 cfs. Instantaneous standards (e.g., 4 mg/l DO) should then be achieved whenever the instantaneous flow is greater than 100 cfs. Two interpretations appear possible for daily average standards (e.g., 5 mg/l DO): (1) the standard should be achieved as a daily average whenever the daily average flow is greater than 100 cfs; or (2) the standard should be achieved as the daily average of all times in which the instantaneous flow is greater than 100 cfs. These two interpretations can yield different results when continuous observations or model predictions of DO are available. The first alternative is more stringent, as DO concentrations at flows less than 7Q10 may be included in a daily average, as long as the daily average flow is greater than or equal to the 7Q10 flow. For instance, consider a river with a 7Q10 of 100 cfs and 24-hour period in which 12 hours of flow are at 50 cfs and a DO of 3 mg/l and 12 hours of flow are at 150 cfs and a DO of 5 mg/l. The daily average flow is equal to the 7Q10 flow. The first interpretation of applicability yields a daily average DO concentration of 4 mg/l. The second interpretation, which allows exclusion of the 12 hour period with flow less than 7Q10, yields a daily average concentration of 5 mg/l for purposes of application of the standard. The issue is not, however, relevant to the "critical condition" model applications submitted by DHEC as long as boundary flows are held at appropriate design conditions.

The "point one" rule in the antidegradation statement does not contain a specific note as to applicable flow conditions. However, since the "point one" rule refers to conditions in which standards are not achieved, and standards are only applicable at flows greater than or equal to the

7Q10 flow, the "point one" rule also can be inferred to be applicable at flows greater than or equal to the 7Q10 flow.

The applicability clause is written for uni-directional flowing streams in which the 7Q10 flow is readily determined. In tidal systems, 7Q10 may not be readily measured, and the interpretation is much less clear. The intent of the standards appears clear, however, that allocations for these types of waterbodies should be designed to restrict excursions of the DO standard to an acceptably low frequency, rather than prohibiting excursions under all extreme low dilution conditions. Potential minimum dilution design conditions for tidal systems are discussed further in Section 5.

3. Use of Dynamic Models for Wasteload Allocations

Applicability of Dynamic Models to DO Analysis in Tidal Systems

In wasteload allocations, models are applied to determine and predict attainment of water quality standards. Therefore, appropriate model application and interpretation of model output should be consistent with the applicable state standards. Traditionally, most wasteload allocations have relied on steady state modeling at design conditions representative of a rare event with a specified probability of occurrence. Where appropriate, steady state models are recommended for wasteload allocations because they are simpler to apply and easier to interpret. In certain situations, however, steady state modeling does not provide an accurate estimate of the probability of excursions of a standard resulting from a wasteload allocation. The steady state approach yields only the probability of standard excursions at design conditions, and does not yield the full distribution of environmental outcomes. This is appropriate when a design condition associated with an acceptable low probability of excursion of the standard is identifiable—for instance, when an effluent discharges oxygen-demanding waste into a uni-directional flowing stream, such that impact on DO is at a maximum when dilution capacity is lowest, temperature-dependent oxygen saturation is lowest, and temperature-dependent reaction rates are highest. To determine design or critical conditions, a suitably rare combination of low dilution flow, high water temperature, and other relevant factors is selected. A steady state wasteload allocation at such design conditions then ensures that excursions of the standard will not occur at more common higher flow and lower temperature combinations. If, however, a design condition is not identifiable, steady state wasteload allocations under a particular set of conditions cannot ensure a specific low frequency of excursions of the standard under other conditions. Use of steady state models also does not explicitly consider the effects of correlation between dilution capacity and variable effluent loads. For instance, precipitation-driven nonpoint loads are associated with higher instream dilution flows, and analysis at steady state 7Q10 design conditions can lead to overly-stringent results.

For tidal waterbodies, flow is not uni-directional, but changes in magnitude and oscillates with the tidal cycle. It is still possible to define critical, minimum dilution conditions within a tidal system (see Section 4); however, a steady state analysis at the minimum dilution condition is not sufficient to provide an accurate time course prediction of DO concentrations, because DO will depend on the extent of mixing of oxygen-demanding waste in the period leading up to the minimum dilution condition, and critical DO concentrations may not coincide in time with minimum dilution.

In contrast to a steady state analysis, dynamic modeling approaches attempt to reproduce the actual time series or distribution of instream concentrations and explicitly include the effects of variability in dilution capacity and effluent load over time. A full dynamic modeling analysis can predict the entire effluent concentration frequency distribution, thus allowing wasteload allocations to be set to produce an expected frequency of excursions of the standard.

Steady state analyses are still useful for tidal systems, particularly for initial scoping analyses. They are particularly useful for approximating concentrations averaged over a tidal cycle. For DO problems a steady state analysis cannot, however, provide accurate estimates of intra-tidal instantaneous concentrations. South Carolina water quality standards specify both daily average and instantaneous DO concentrations. Thus, a dynamic, intra-tidal modeling analysis is appropriate for accurate determination of a wasteload allocation.

DHEC Dynamic Model Applications

For two waterbodies—the Waccamaw/Intracoastal Waterway and the Cooper River—DHEC, in conjunction with USGS, has conducted dynamic DO modeling using the BRANCH/BLTM model (Drewes and Conrads 1995, Conrads and Smith 1997). BRANCH/BLTM is a USGS one-dimensional, unsteady-flow model coupled with an unsteady water-quality transport model which is applicable to tidal systems lacking significant stratification. Both models have a credible record of application by USGS and others. DO and nutrient kinetics of the BLTM model are the same as those included in EPA's QUAL2E model.

A technical review of model application was not specifically requested for this SWAT response; however, a cursory review of the model set-up and calibration did not uncover any unreasonable assumptions. Synoptic water quality data available for calibration were, however, limited. The Waccamaw/Intracoastal Waterway model was calibrated to data for April 10-25, 1990, while the Cooper/Wando model was calibrated to data for August 23-25, 1993 and validated on data from May 4-5, 1993. For the Waccamaw/Intracoastal Waterway system, USGS developed assimilative capacity curves that show assimilative capacity conditional on seven-day average influent streamflows. For the Cooper/Wando model, the primary freshwater input is controlled by Pinopolis Dam, and USGS reported simulations for several different assumptions of flow over this dam.

One significant difference between the Cooper and Waccamaw models is that the Cooper model includes algae in the simulation, while the Waccamaw model does not. This is typically a difficult issue for DO wasteload allocation modeling. Algae can have a significant effect on the DO balance, but are difficult to represent accurately in dynamic models. Under many conditions algae lead to a net increase in DO; however, at a saltwater/freshwater interface the die-off of freshwater algae can sometimes result in a high oxygen demand. It is often necessary to include algae in a DO model to obtain calibration to synoptic data, unless the effect of algae on the DO balance can be shown to be insignificant. Inclusion of algae in a wasteload allocation model is a different matter. While algae may increase DO during calibration observations, algal populations are highly variable, and may not always mitigate effects of oxygen-demanding waste. An available option to account for the effects of algae but still ensure the highest possible accuracy, is to calibrate and validate the model including the algal component, but then run the model with and without algae, using the more stringent result for the wasteload allocation.

4. Interpretation of Dynamic Modeling Output: Averaging Periods

DHEC extended the USGS model applications for the Waccamaw and Cooper Rivers by adjusting the calibrated, validated BRANCH model to a critical conditions model. First, assumptions were made for design conditions of flow and other relevant parameters (see Section 5 for a review of design condition assumptions). For the Waccamaw, the analysis was based on examination of the June to September flow records for the year of calibration, with the most critical month selected for each permitted facility (September for some, July for others). For the Cooper river the model uses an observed late summer month of flow conditions, except that some synthesized flows are used for the dam. The last two weeks of the simulation period is at dam releases equal to the limiting flow specified in the dam operation agreement (personal communication from Nancy Sullins, SC DHEC, 1/12/98). In both water bodies the DO standards are not expected to be attained due to natural conditions at low flow conditions, so the "point one" rule is applied to analysis of wasteload allocations. DHEC then applied the model as follows:

> DHEC has chosen to run the BRANCH/BLTM model for six weeks, two weeks for model warm up and four weeks of the critical month. First, a no load run is made without discharger inputs. Then the model is run with the dischargers permitted loads included. The outputs are compared, time step by time step, and twenty-four hour running averages of the differences between the two scenarios are determined. Adjustments are made in the "with load" scenario to determine the maximum loading that will not result in any twenty-four hour period having an average deficit greater than 0.1 mg/l. The load associated with this 0.1 mg/l change is then identified as the maximum allowable load for that reach of the water body. A twenty-four hour running average was chosen with the thought that any averaging period longer than twenty-four hours would reduce the variability of the predicted dissolved oxygen. This softening of the curve reduces the

effectiveness of the model to predict periods which may cause stress to the biological community.

The DHEC analysis of attainment of standards is based on running twenty-four hour averages calculated from a critical low flow month, with other design conditions held constant. Instantaneous predictions were not used to assess attainment.

Examination of issues surrounding the averaging period was included in review of the analysis. The water quality standards express an instantaneous DO standard (4 mg/l) and a "daily average" DO standard (5 mg/l). Therefore, for waters which would attain the standards under natural conditions, it would be appropriate to compare both each instantaneous prediction and the twenty-four hour averages in model output to the appropriate standard.

Similarly, in naturally non-attaining waters where the "point one" rule applies, both instantaneous and daily average values are appropriate for measurement to compare to the water quality standards. For any point in time when the instantaneous DO under natural conditions would be less than 4 mg/l the wasteload allocations allows no more than an 0.1 mg/l lowering of instantaneous concentration, and for any day in which the average DO under natural conditions would be less than 5 mg/l the wasteload allocations allows no more than an 0.1 mg/l lowering of the twenty-four hour average concentration.

Options for calculation of the twenty-four averages include use of a running average, or use of a discrete average concentration over a specified diurnal cycle (e.g., sunrise to sunrise). The two methods do not necessarily provide the same result under dynamic conditions, and the running average would be more stringent, as it can "seek out" and combine adjacent parts of two days in which concentration is abnormally low. However, the use of running twenty-four hour averages may overestimate the accuracy of the model. In general, DO models should be better at predicting the average over a diurnal cycle than instantaneous concentrations. Therefore, it might be more appropriate to evaluate daily averages on a fixed (rather than running) twenty-four hour period.

According to DHEC, "There has been concern expressed by the regulated community that the twenty-four hour running average is overly conservative and a seven day average is more appropriate for tidally influenced systems." The South Carolina standards refer to the twenty-four hour average and minimum concentrations and not a 7-day average. The fact that the flow regime under which the standard is applicable is based on the 7Q10 flow is not relevant to the standard averaging period. Finally, it should be noted that the appropriate interpretation of dynamic model output is dependent on how the design conditions are specified. These issues are addressed in the following section.

5. Design Conditions for Dynamic Modeling

Dynamic versus Quasi-Dynamic State Applications

For tidal systems, dynamic modeling of DO is recommended to capture complex patterns induced by tidal mixing, particularly for prediction of instantaneous DO concentrations. DHEC adopted a dynamic modeling framework primarily because appropriate design conditions for flow in tidal systems were not readily identifiable. Model calibration to synoptic data also implicitly includes the effects of variability in nonpoint and background pollutant loads, although this is not explicitly addressed in the wasteload allocation applications.

As noted above, a full dynamic modeling analysis can predict the entire effluent concentration frequency distribution, thus allowing wasteload allocations to be set to produce an expected frequency of excursions of the standard. A full dynamic analysis, however, requires a substantial level of effort and data. For instance, if recurrence intervals of 10 or 20 years are desired, at least 30 years of continuous simulation is needed to provide a sufficient record to estimate the probability of such rare events (USEPA 1991).

While DHEC has employed a dynamic model, the wasteload allocation procedure is not a full dynamic analysis; sufficient flow data are not available to undertake long-term simulation. Instead, DHEC has used the dynamic model to represent internal flow and mixing processes, and to implicitly determine critical flow conditions. The wasteload allocation analysis was then performed with other critical conditions, such as temperature, held constant. This may be termed a quasi-dynamic model application. Although based on dynamic flows, it is still essentially a design condition analysis.

This section reviews the various components of the quasi-dynamic design condition specification.

Approximate Minimum Dilution Design Conditions for Tidal Systems

In typical steady state wasteload allocation modeling, a design low flow such as the 7Q10 is used. This design flow has a low dilution capacity for effluents, and is used to implicitly establish an acceptable frequency of excursions of the standard associated with a wasteload allocation for a steady source. Within tidal systems, the concept of 7Q10 flow does not directly apply, although a 7Q10 flow of freshwater influent to the tidal system can be estimated. More importantly, dilution capacity of a tidal system is a function of both the inflow of fresh water and tidal flushing.

DHEC has adopted a quasi-dynamic modeling approach to represent tidally-driven mass fluxes and intratidal variability of concentrations within the waterbody. Boundary conditions are held constant in the quasi-dynamic application. Because simulation is not undertaken for the long period of time necessary to establish actual average excursion frequencies, it is important to ensure that the simulation design conditions represent a suitable level of criticality in dilution capacity. A steady-state analysis would be sufficient to establish wasteload allocations. Although more than one option might be appropriate, an example approach for tidal systems is to use an analysis based on a minimum dilution level which is analogous to the 7Q10 flow used for steady state wasteload allocations in streams. USEPA (1991, p.74) makes the following recommendation for estimating critical dilution conditions for toxics in estuaries:

> In estuaries without stratification, the critical dilution condition includes a combination of low-water slack at spring tide for the estuary and design low flow for riverine inflow. In estuaries with stratification, a site-specific analysis of a period of minimum stratification and a period of maximum stratification, both at low-water slack, should be made to determine which one results in the lowest dilution... Recommendations for a critical design period for coastal bays are the same as for stratified estuaries.

This approach is most applicable to acute or instantaneous standards for toxics in which intra-tidal variability must be considered and maximum impact is expected at the point of discharge of an effluent. For BOD/DO problems, reactions and transport within the system must also be considered and maximum DO deficit may not coincide in time with minimum dilution; it would be advisable to examine a combination of design low flow (7Q10) in riverine inflow with both spring and neap tidal ranges, which determine the maximum and minimum values of tidal mixing. With this approach, it would be helpful to examine instantaneous DO concentrations and daily average conditions over a full lunar cycle.

Physical and Chemical Components of Design Conditions

A number of factors other than flow or dilution capacity affect the impact of BOD loads on DO concentrations. Most notable among these is temperature: higher temperatures decrease the saturation concentration of oxygen in water, and increase reaction rates which deplete DO. The DO balance is also affected by wind-driven reaeration and influent (freshwater or tidal) concentrations of DO, BOD, and nutrients (which affect algal growth and thus DO). Design conditions for DO/BOD analysis should specify a variety of other physical and chemical factors in addition to flow. This is done automatically in a full dynamic simulation; in the quasi-dynamic approach, fixed boundary values of these supplementary parameters are specified externally. While using a dynamic simulation of flows, DHEC has specified additional critical conditions as steady state at the boundaries using the following rule:

> In-stream water temperature, DO, NH_3-N, NO_2, NO_3, PO_4, and BOD_5 critical values are determined by identifying the 95th percentile of all parameters except for DO, where the 5th percentile was identified, for the given month from STORET station monthly

sampling data located within the model's domain. These percentiles were chosen with the thought that since a 7Q10 critical flow period approximates a 95th percentile the other parameters should approach the same criticality.

The 7Q10 critical flow does not specifically represent a "95th percentile." The 7Q10 is calculated as a minimum annual 7-day average which recurs once every ten years on average—so, on average, one or more 7-day flows at least this low will be seen in one out of ten years (10% of years). The 7Q10 is based on annual minima, and is not simply related to the actual frequency of 7-day flows. In the terminology of USEPA (1986), the 7Q10 is a hydrologically-based recurrence interval, whereas the actual recurrence of all low dilution flows (not just annual minima) is called a "biologically-based" recurrence interval. Further, the South Carolina standards are based on 1-day or instantaneous flows, not 7-day flows, even though the 7Q10 is used to establish the critical flow. Based on the analysis in USEPA (1986), the 1-day biologically-based dilution flow with a 3-year recurrence interval averages approximately 90% of the 7Q10 flow. Therefore, a 1-day flow at the 7Q10 value should occur in *at least* one out of three years, only 0.09% of days.

A second concern is that if a 95th (or other) percentile level is desired, this is not properly obtained by taking the 95th percentile value of each of seven observed parameters, unless the distributions of these parameters are perfectly correlated. For example, assume that each of the parameters is independent. For each parameter, a value equal to or greater than the 95th percentile occurs 5% of the time. The probability of all seven parameters exceeding the 95th percentile at the same time (if independently distributed) would be $0.05^7 = 7.81 \times 10^{-10}$, or the 99.9999999th percentile. Even for three parameters (e.g., temperature, DO, and BOD, as required for the Waccamaw model), the probability of all parameters exceeding the 95th percentile (if independently distributed) is equal to the 99.9875th percentile. Although, some of these parameters will be strongly correlated (e.g., the nitrogen series), increasing the probability of co-occurrence. Others, however, (such as temperature and BOD_5) may be negatively correlated, which decreases the probability of co-occurrence. Further, the analysis assumes that the 95th percentile of these parameters is uncorrelated to the occurrence of minimum flow, whereas nonpoint washoff processes may result in a positive relationship between flow and pollutant concentrations, and perhaps a negative correlation between flow and temperature.

Determining appropriate critical conditions for multiple parameters is a difficult issue. It is possible, however, that choosing the 95th percentile (5th percentile for DO) of each of these parameters could lead to an analysis which is more stringent than is intended. Indeed, if analysis with the 7Q10 dilution flow is assumed to implicitly establish an allowed frequency of excursion of the standard, selection of extreme values for other design conditions would result in holding the allocations to a lower allowed frequency of excursions than is implied in the regulation. Unfortunately, the fact that the distributions are likely to be non-normal and correlated means that an analysis with the other design conditions simply set to monthly mean values may under-estimate the actual frequency of excursions.

There are various approaches which can be taken here. One is to impose a protective, but more conservative assumption. For instance, the State of North Carolina sets each of these auxiliary design parameters at the outer edge of the interquartile range (75^{th} or 25^{th} percentile) of the observed summer distribution in a wasteload allocation. This is essentially an *ad hoc* compromise designed to avoid highly stringent results while retaining a (likely) conservative approach. This percentile was selected based on non-parametric analysis which suggested it provided a good representation of the actual frequency of excursions of standards (personal communication from Trevor Clements, former Chief, Technical Support Branch, Water Quality Section, NC Division of Environmental Management, now with Tetra Tech, 1/13/98).

A more rigorous alternative to specifying steady design boundary conditions is to undertake a multivariate analysis. This is the approach used in EPA's (1988, 1991) DESCON model. While DESCON is not directly applicable to tidal systems, the general approach is relevant. DESCON estimates design conditions based on maintaining a specified desired limit on the frequency of water quality excursions in a receiving water. DESCON considers the effects that daily fluctuations in stream flow and other water quality conditions have on the capability of a receiving water to accept pollutant loadings, while explicitly accounting for the correlation present among design variables. The general approach is as follows (USEPA 1991):

1. A long-term record of observed stream flows and pertinent water quality data are assembled or synthesized.

2. The maximum allowable pollutant load that the receiving water can accept without causing a water quality excursion is computed for each day of this record.

3. This synthesized record of allowable loads is searched for the critical load, i.e., the load whose frequency of not being exceeded matches the desired water quality excursion frequency.

4. Design conditions are then derived from receiving water conditions realized during the period of record when the computed allowable load was closest to the critical load.

Unfortunately, this type of approach would be difficult to implement for the complicated tidal flow patterns of the Waccamaw and Cooper Rivers. Further, available data might not be sufficient to support such an approach. Therefore, a simpler *ad hoc* approach (such as choosing 75^{th} percentile values) is a more viable option.

However, a full long-term dynamic simulation would avoid these issues by directly representing the interactions between all parameters.

Based on the discussion on the previous pages, the following options for additional design or critical condition analysis are provided:

- Set upstream uncontrolled freshwater inflows to 7Q10 flows, consistent with state regulations to represent minimum dilution design conditions while keeping a dynamic seaward boundary condition. For Pinopolis Dam, set overflows to minimum specified in operational agreement.

- Select seaward tidal boundary conditions to represent the range of spring to neap tides. This is probably best done by simulating a lunar month (from first quarter to subsequent first quarter) with the addition of a sufficient model spin-up period.

- Set seaward boundary temperature and constituent concentrations to 75th percentile values (25th percentile for DO).

- Set freshwater inflow temperature and concentration to *either* median observed at low flow conditions, *or* 75th percentile values for summer months.

- Test sensitivity of model to boundary conditions.

6. Permit Limits

The procedure set out by DHEC yields wasteload allocations to result in compliance with the "point one" antidegradation rule. Appropriate statistical methods are discussed in EPA's (1991) TSD for Toxics. This approach to statistically-based permit limits is included as a point of discussion. It is not often applied to DO/BOD problems, but does represent a way to obtain sophisticated and accurate permit limits appropriate to dynamic model output. Other options are available that are appropriate for determining permit limits.

References

Conrads, P.A. and P.A. Smith. 1997. Simulation of Temperature, Nutrients, Biochemical Oxygen Demand, and Dissolved Oxygen in the Cooper and Wando Rivers near Charleston, South Carolina. Water-Resources Investigations Report 97-4151. U.S. Geological Survey, Columbia, SC.

Drewes, P.A. and P.A. Conrads. 1995. Assimilative Capacity of the Waccamaw River and the Atlantic Intracoastal Waterway near Myrtle Beach, South Carolina, 1989-92. Water-Resources Investigations Report 95-4111. US Geological Survey, Columbia, SC.

USEPA. 1991. Technical Support Document for Water Quality-based Toxics Control. EPA/505/2-90-001. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

USEPA. 1988. Technical Guidance on Supplementary Stream Design Conditions for Steady State Modeling. (Technical Guidance Manual for Performing Wasteload Allocations, Book 6, Chapter 2). Office of Water Regulations and Standards, U.S. Environmental Protection Agency, Washington, DC. Unpublished; available from Exposure Assessment Branch, Office of Science and Technology, U.S. Environmental Protection Agency, Washington, DC.

USEPA. 1986. Technical Guidance Manual for Performing Wasteload Allocation. Book VI: Design Conditions; Chapter 1: Stream Design Flow for Steady-state Modeling. EPA 440/4-87-004. Office of Water Regulations and Standards, U.S. Environmental Protection Agency, Washington, DC.

Attachment B: Model Segmentation

The approach used to apply the allowable daily average 0.10 mg/L impact in the recently approved Cooper TMDL was based on dividing the system into segments with similar chemical and physical characteristics and calculating a volume-weighted daily average delta DO for each segment (Greenfield, 2002). The critical segments were the lower Cooper River from Goose Creek to the mouth (river mile 6.3 to 13.7) and the Cooper/Wando estuary (river mile 4.2 to 6.3). A similar approach is recommended for the Ashley River TMDL. The segment boundaries are based on simulated river hydraulic, transport, and dilution characteristics as well as the predicted longitudinal extent of the DO impact.

Average simulated hydraulic data for the Ashley River at the two pipe locations are summarized in Table 12. The data are based on TMDL river conditions and existing permit limits for pipe flows.

Table 12. Average Simulated River Hydraulic Data

Parameter	At Pipe 1 Location (model mile 4.0)	At Pipe 2 Location (model mile 9.4)
Area (ft^2)	950	4872
Top Width (ft)	212	350
Ebb/Flood Flow (cfs)	281/381	2,697/2,928
Ebb/Flood Velocity (ft/s)	0.39/0.29	0.62/0.54

Transport was evaluated by simulating the discharge of a conservative tracer. Tracer simulations were performed by USGS and output provided to DHEC. Flow conditions were a steady state 5 cfs at the upper boundary, and 9.03 cfs and 4.12 cfs for Pipe 1 and Pipe 2, respectively. Note the flows used by USGS for the tracer runs are the pipe flows assumed for the previous TMDL which are less than current permit flows of 15.84 and 6.21 cfs, respectively. Pipe tracer concentration was 50 mg/L. Three runs simulated (1) both pipes on, (2) Pipe 1 only, and (3) Pipe 2 only. Figure 2 shows results for Pipe 1 over a single tidal cycle from hour 882 to hour 894. Peak tracer concentrations from Pipe 1 were predicted from the outfall to a point about 1 mile downstream with little response below mile 7.

Figure 2. Tracer Response for Pipe 1 at SS 5 cfs Boundary Flow

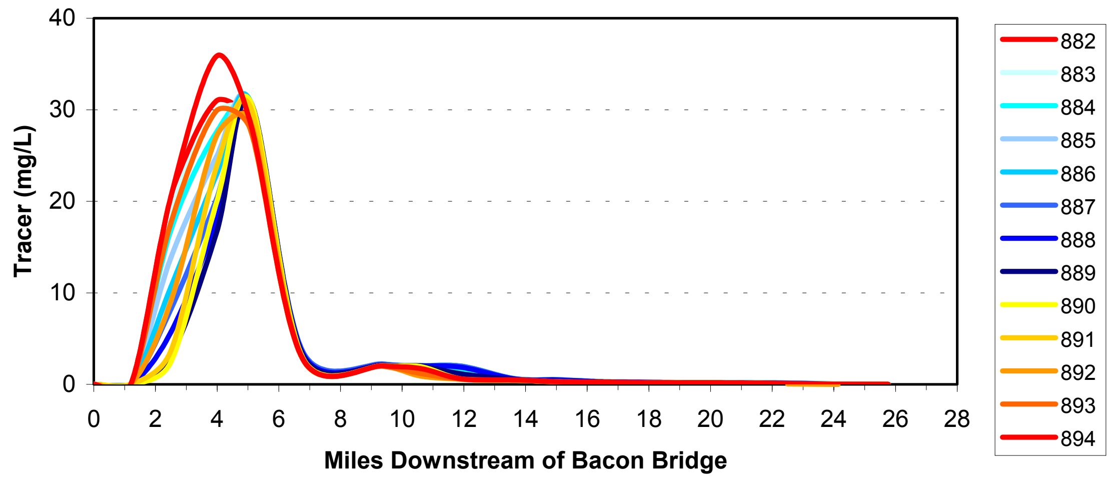


Figure 3 show results for Pipe 2; peak concentrations occurred over the segment from mile 7 to mile 12.

Figure 3. Tracer Response for Pipe 2 at SS 5 cfs Boundary Flow

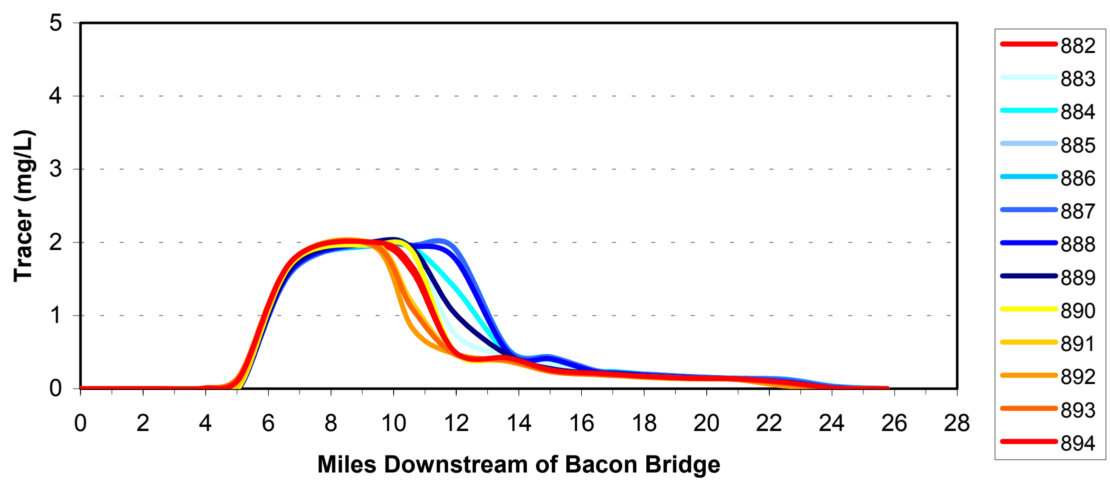


Figure 4 shows the maximum 24-hour average tracer concentration during the simulation. Note the loading was a little more than twice as high from Pipe 1 than Pipe 2. Using the peak concentrations from the individual pipe runs, dilution at each location was estimated. Results are shown in Table 13.

Figure 4. Maximum 24-hour Tracer Response at SS 5 cfs Boundary Flow

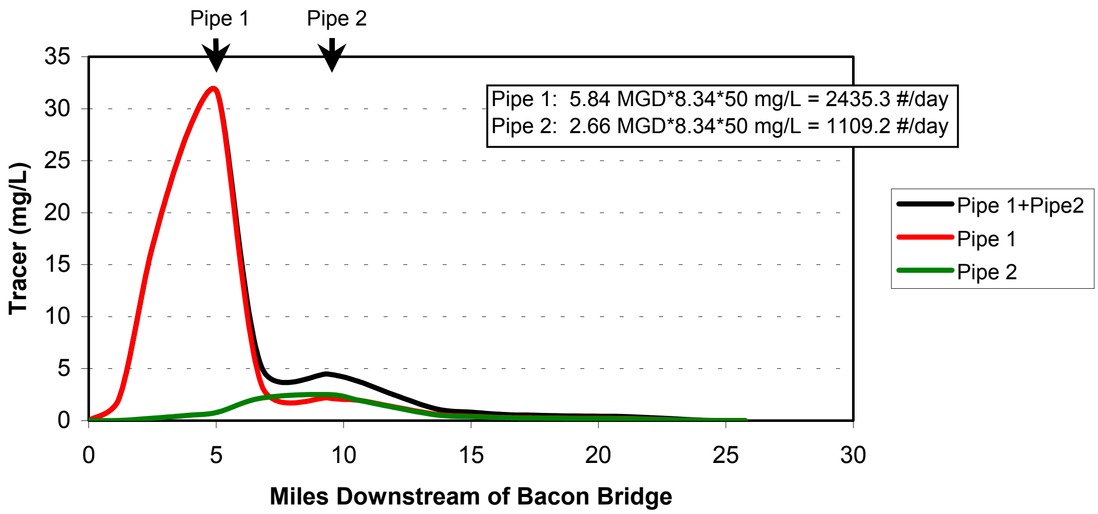


Table 13. Dilution Estimated from Tracer Results

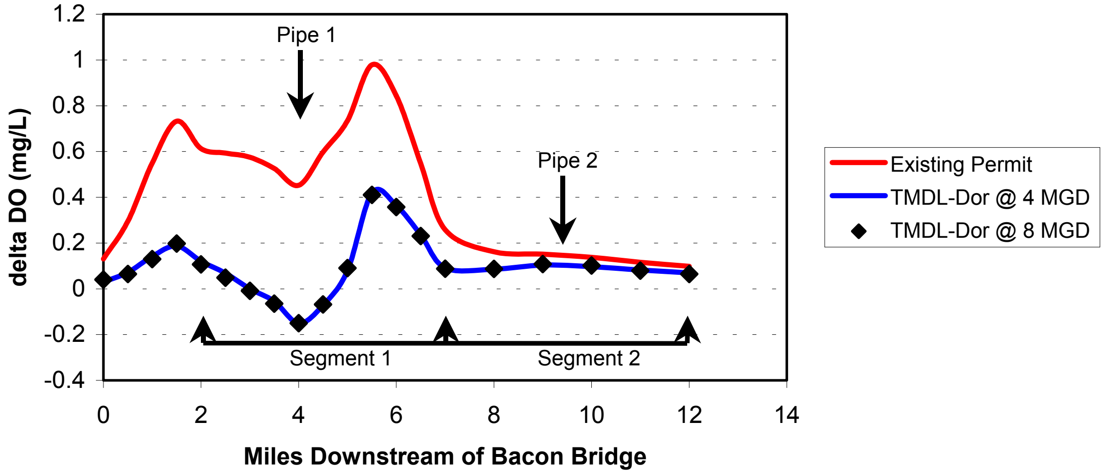
Pipe	Pipe Flow (cfs)	Pipe Concentration (mg/L)	Instream Concentration (mg/L)	Total Dilution[1] (cfs)	Ambient Dilution[2] (cfs)
1	9.03	50	31.4	14	5
2	4.12	50	2.52	82	78

[1]total dilution = pipe flow*pipe conc./instream conc.
[2]ambient dilution = total dilution - pipe flow

Note the flow conditions used for the tracer runs are different than the flow conditions used in the TMDL model, but these results show the relative difference between the two locations. In addition, although Dorchester is modeled at Pipe 1 for the DO TMDL on the Ashley River, the outfall is actually located on a tributary creek, and the dilution used for toxicity evaluations for Dorchester will be based on the creek.

The predicted maximum daily average DO impact at existing permit loads, TMDL loads (Dorchester @ 4 MGD), and TMDL loads (Dorchester @ 8 MGD) are shown in Figure 5. The segment boundaries are also shown.

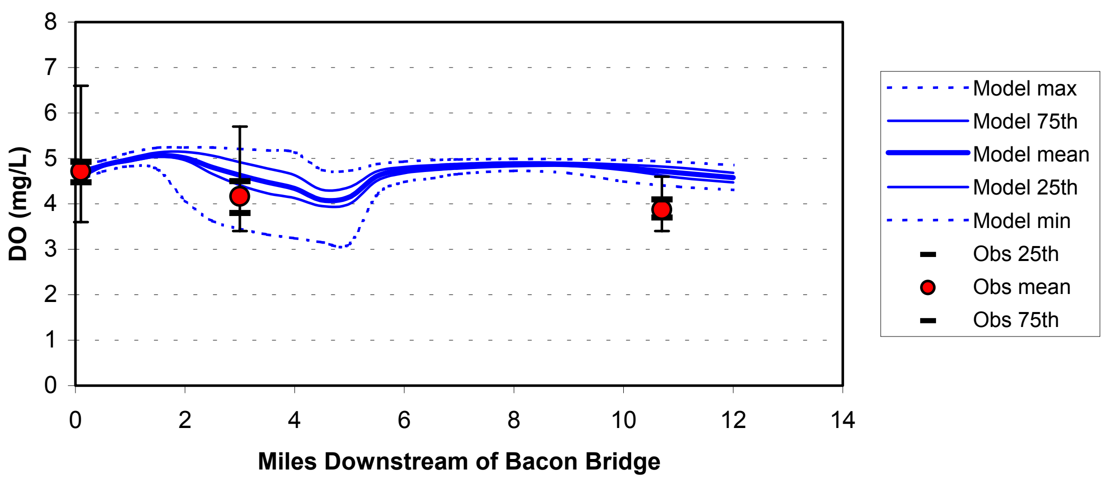
Figure 5. Predicted DO Impact in Segments 1 and 2



Attachment C: Comparison of Predicted No-load DO to Instream Data

TMDL model no-load DO was checked against available instream data to verify the critical conditions model results are reasonable. Figure 6 shows DO concentrations predicted by the TMDL no-load run during the last 30 days of the simulation and USGS published DO concentrations at stations 02172081 (Bacon Bridge), 021720812 (3 miles below Bacon Bridge), and 02172084 (10.7 miles below Bacon Bridge) during July and August 2000-2001 (02172081) and 2000 (021720812 and 02172084). The measured data are not corrected for salinity and temperature. Based on this comparison, the TMDL model predictions are considered reasonable and consistent with actual conditions in the Ashley River.

Figure 6. TMDL Model No Load DO vs. Observed Data



APPENDIX D

EPA Review of Modeling Approach

Mr. Alton Boozer August 15, 2002
Chief, Bureau of Water
South Carolina Department of Health
And Environmental Control
2600 Bull Street
Columbia, South Carolina 29201

Dear Mr. Boozer:

I have reviewed the draft SC DHEC Ashley River TMDL and the USGS BLTM re-calibration modeling report. I concur that the proposed TMDL and WLA results are within the range needed to meet SC DHEC's WQS water quality standards and that the BLTM model was appropriately applied to develop these results. The upper Ashley River is a complex hydrodynamic and water quality system driven by tidal flow impacts and marsh / wetland contributions, both which impact the D.O. regime of the system. The phased approach SC DHEC proposed is the appropriate long-term mechanism to address the impacts of both point and non-point sources. The first phase addresses the point source impacts and based on the SC 0.1 D.O. rule, results in loadings for the two existing discharges that meets the 0.1 rule while SC DHEC continues to address non-point sources of pollution through existing programs.

The BLTM model provides an adequate and an appropriate level of analysis for addressing the point source concerns. The kinetic rates used in the model are within the expected ranges and the model simulates measured instream conditions. While it may not be able to precisely predict the actual instream D.O., the model results are in the appropriate range and the model is precise enough to predict changes in DO of 0.10 mg/L resulting from effluent loading. Therefore, in my opinion the TMDL and the proposed wasteload allocations are both reasonable, within the range of reductions needed and technically defensible. As with any TMDL or modeling study, additional data collection and analyses would help to develop a better help to develop a better understanding of this complex system.

If you have questions regarding my report review, or if I can be of further assistance, please call me at 404/562-9238.

Sincerely,

James Greenfield,
Senior TMDL Modeler
Water Management Division

APPENDIX E

Responsiveness Summary to Public Comments on the Initial Draft Ashley River TMDL

SUMMARY OF PUBLIC COMMENTS AND DEPARTMENTAL RESPONSES
FOR DRAFT TOTAL MAXIMUM DAILY LOAD (TMDL) FOR THE ASHLEY RIVER
(Based on December 2000 Draft TMDL Notice)

Note: The Department received a significant number of comments from a variety of commenters regarding the initial draft Ashley River TMDL that included governmental entities and environmental organizations. The Department has organized this responsiveness summary so that the comments will appear grouped by the issues to which they apply. There is no inference of importance or meaning given to the order in which the comments are addressed. A list of those commenting on the draft TMDL is attached.

Issue: Several commenters expressed concerns over the adequacy of the BRANCH/BLTM model and questioned its use as a tool to model the Ashley River system.

In addition to the specific responses below, the Department notes the Ashley River BRANCH/BLTM model used by DHEC for the TMDL was developed by USGS and approved by EPA as a suitable tool for this analysis.

1) Comment: The 1-dimensional BRANCH/BLTM models are not suitable for use in tidally influenced estuarine systems such as the Ashley River because they cannot capture the complex hydrodynamics of a multi-dimensional system, and they are not accurate enough to apply the Tenth Rule.

   Response: DHEC acknowledges that the 1-dimensional BRANCH/BLTM model may not be applicable to all estuaries. However, DHEC considers BRANCH/BLTM to be applicable to the Ashley River. The commenter is referred to the original USGS model report, Conrads (1998), which states BRANCH/BLTM is appropriate to apply to the Ashley River because there is little stratification for extended periods, and the complex geometry of tidal marshes and old rice fields can be simplified in BRANCH as large storage areas that fill and drain with each tidal cycle.

   DHEC acknowledges the model is not accurate enough to predict absolute DO concentrations to within 0.10 mg/L. However, we consider the model to be precise enough to predict changes in DO of 0.10 mg/L resulting from effluent loading. We note BRANCH/BLTM was successfully applied to the Waccamaw River and Atlantic Intracoastal Waterway to develop an approved TMDL under the Tenth Rule and believe the same approach is applicable to the Ashley River.

2) Comment: Simplifying assumptions used to represent the marsh areas in the model and in the grid configurations of the BRANCH and BLTM models necessitated post-processing of BRANCH output for use by the BLTM and call into question the

accuracy of the model results. This resulted in the model's inability to accurately predict pollutant transport in the Upper Ashley River System.

Response: All models contain simplifying assumptions. BRANCH and BLTM were successfully calibrated while representing the marshes as water storage areas (Conrads, 1998). The representation of the marsh areas in the TMDL model is the same as the representation used in the calibrated model. DHEC concurs with USGS and EPA modelers that this representation is reasonable for the Ashley River model.

As stated in Conrads (2003), the model schematization was chosen to minimize numerical dispersion, i.e., to improve accuracy. The commenter is referred to Conrads (2003) for a detailed discussion. As with the representation of the marshes, the grid configuration used in the TMDL model is the same as the calibrated model.

3) Comment: The model calibration using salinity was improper because BLTM is a 1-dimensional model and cannot properly simulate the movement of salinity, and the model was artificially adjusted to force acceptable salinity comparisons. This resulted in unsatisfactory prediction of transport (i.e., flow) in the Upper Ashley River.

   Response: The model was calibrated to water level and flow in addition to salinity plus the eight state water quality parameters. Based on USGS, EPA, and DHEC model review, the predicted transport is considered acceptable.

Issue: Application of the Branch/BLTM model is flawed through use of inaccurate model inputs.

4) Comment: It appears DHEC used higher background dissolved oxygen levels (4.11 to 5.12 mg/L) than those measured by USGS. Current data should be reviewed to verify this key model component.

   Response: Current data were reviewed and used to update background values for all constituents as described in Section 4.4 of the TMDL model report included as Appendix C. The upper boundary DO concentration was set to 4.5 mg/L, the 25th percentile of measured data at USGS station 02172081 during July and August 2000-2001. The lower boundary was set to 4.81 mg/L, the 25th percentile for DHEC station MD-052 during July and August 1996-2001. These values were chosen as recommended by Butcher (1998) and are considered appropriate for this evaluation.

5) Comment: DHEC used an inappropriate nitrification rate. The combination of 1.0/day for ammonia to nitrite and 0.2/day for nitrite to nitrate used for the Ashley River is more than 30 times higher than the site-specific rate developed for the

Savannah River. DHEC should document why such a high nitrification rate was used in light of the Savannah River rate, which we believe is equally applicable to the Ashley River.

Response: The nitrification rate was reviewed and updated taking into account recent site-specific field data for the Ashley River. The current model uses 0.2/day for ammonia to nitrite and 0.4/day for nitrite to nitrate. The determination of these rate coefficients is described in Conrads (2003).

6) Comment: The light penetration coefficient is impossible.

   Response: The comment appears to refer to the light extinction or light attenuation factor listed in Conrads (1998). USGS investigated this concern and determined the 0.1/m value listed in the report is a typographical error; the actual value that was used in the model is 0.7/m (Conrads, 2003). The current model, like the original model, uses the correct value of 0.7/m.

Issue: Several commenters questioned the quality and adequacy of the data used to calibrate the Branch/BLTM model.

7) Comment: DHEC had insufficient data to properly develop a TMDL. This comment expressed concern that a significant portion of the data was only measured one time, was not corrected for wet and dry weather effects, was not corrected for other events (such as spring and neap tides), was outdated because it was collected before load reductions made during 1995, or was collected with no consistent data collection protocol.

   Response: The model is based on a significant data collection effort by USGS during 1992-1995 as part of the Charleston Harbor Project. USGS also reactivated sampling stations on the Ashley River in 2000. In addition, DHEC operates long-term monthly sampling stations throughout the Ashley River. Long-term meteorological data for Charleston Airport are collected by the National Weather Service and are readily available. This information represents a significant dataset that is suitable for TMDL development.

   The concern regarding the load reductions resulting from the Summerville WWTP upgrade in 1995 is valid. The current model has been updated to represent current conditions in the Ashley River. The commenter is referred to Conrads (2003) for information on updates to the model kinetics, including the nitrification rate, and to Section 4.4 of the TMDL model report included as Appendix C, which describes the data used to determine water quality boundary conditions.

Issue: Several commenters questioned the adequacy of DHEC's documentation of the model development process.

8) Comment: It is unclear whether DHEC included the marsh exchanges in the model runs.

   Response: As noted above, the representation of the marsh areas used in the TMDL model is the same as the calibrated model.

9) Comment: DHEC could not document its verification of the no-load output under critical conditions.

   Response: No-load DO predicted by the current TMDL model was compared to available instream monitoring data, as recommended by EPA. Results appear in the TMDL model report included as Appendix C. This comparison confirmed the TMDL model predictions are reasonable and consistent with conditions observed in the river.

Issue: Several commenters stated that the TMDL model, wasteload allocation development process and process for including a margin of safety were not adequately documented.

10) Comment: The TMDL model was not properly documented.

    Response: The current TMDL model is documented in this report and the attached appendices. The final TMDL model was provided the Berkeley, Charleston, Dorchester Council of Governments (BCDCOG) on April 17, 2003 for their review and use in allocation of available assimilative capacity among affected permit holders. The final calibration, no-load and TMDL model runs will become part of the administrative record for this TMDL and will be provided upon request.

11) Comment: DHEC was unable to provide its rationale for developing wasteload allocations associated with the TMDL.

    Response: The revised draft TMDL documents the development of "TMDL" loadings and the rationale of why these loadings should serve as the basis for wasteload allocations. These loadings were provided to the BCDCOG for their review and input into final wasteload allocations for the impacted discharges.

12) Comment: DHEC could not document the rationale for and "arbitrary" 10% margin of safety.

Response: The TMDL incorporates an implied margin of safety (MOS) through the use of conservative modeling assumptions. Based on the State/EPA wasteload allocation agreement and EPA's recommendation on use of critical conditions, the critical conditions for flow, tidal conditions, background pollutant loading and discharger loadings are considered appropriate and consistent with accepted modeling conventions. The Department did not use an explicit, 10% MOS when developing the Ashley TMDL. The statement concerning the COG's Section 208 plan was included in the draft TMDL to reflect our understanding at the time that the COG intended to hold 10% of the available load in reserve, not as a MOS but for future growth. That provision is not in the latest COG 208 Plan. Reference to a 10% reserve is not included in the revised draft TMDL.

Issue: Several commenters contended that an adequate uncertainty analysis had not been conducted.

13) Comment: DHEC could not document model sensitivity or a proper uncertainty analysis.

    Response: The sensitivity of the impact (delta DO) predicted by the current TMDL model to critical condition inputs is discussed in Section 7 of the TMDL model report included as Appendix C.

Issue: Several commenters stated that DHEC had used overly conservative kinetic rates in developing the TMDL model.

14) Comment: DHEC appears to have consistently used the conservative end of literature values for the deoxygenation rate, the sediment oxygen demand, dissolved CBOD fraction, and organic matter settling rate. By doing this, DHEC has built into the models an excess of conservatism.

    Response: According to standard wasteload allocation modeling procedure, these inputs are set during the calibration process and are not changed in the critical conditions model used for TMDL development. USGS has evaluated and updated the model kinetic inputs as described in Conrads (2003). All kinetic inputs used in the current TMDL model are the same as those used by USGS in the calibration model.

15) Comment: The model cannot accurately predict dissolved oxygen changes as small as 0.1 mg/L.

Response: The commenter is referred to the Response to Comment 1.

16) Comment: Effluent dissolved oxygen for Summerville should be verified.

Response: The current TMDL model uses the existing permit limit for DO of 7 mg/L for the discharge by the Summerville WWTP.

17) Comment: DHEC's assertion that Applied Technology & Management, Inc. (ATM) confirmed the calibration of the model is not true.

Response: DHEC retracts this assertion.

18) Comment: The proposed TMDL does not provide sufficient information regarding the low flow used in the TMDL analyses. In this location, which is both dam-controlled (the Cooper River) and tidal, the flow data used in the model must be made explicit, and the model must contain the most protective assumptions. *This comment appeared primarily directed at the Cooper River/Charleston Harbor TMDL. However, the comment was part of a single response to the draft TMDLs for both the Cooper River/Charleston Harbor and the Ashley River. The comment is equally applicable to both systems.*

Response: The low flow period used in the previous TMDL was evaluated and updated as appropriate. The commenter is referred to Sections 4.1, 7.1, 7.2, and 7.3 of the TMDL model report included as Appendix C.

19) Comment: DHEC should provide the reaction coefficients and clarify whether they are consistent with those used for the previous model calibration.

Response: DHEC confirms that the reaction coefficients used in the TMDL model are the same as those that were used for model calibration. The values used in both models appear in Conrads (2003).

Issue: Application of the "10% Rule".

20) Comment: Several commenters requested the Department determine the maximum allowable loading as provided by Section D.4.b. of R.61-68 (Water Quality Standards).

Response: R.61-68 provides two options for waterbodies that do not meet standards for dissolved oxygen under certain circumstances. The first is a 0.10 mg/l depression below "background" conditions (the Tenth Rule). The second allows up to a 10% depression below natural background provided it is shown that the most sensitive species present in the system is not adversely impacted by the lower dissolved oxygen levels (the 10% Rule). Though a complex analysis is required to determine the allowable 0.10 mg/L deficit below background, the Tenth Rule can be applied to any situation where the D.O. standard is judged not to be met due to natural conditions. The 10% Rule involves a great deal more site specific evaluation in terms of determining resident species and, if not available, developing information as to the absolute dissolved oxygen requirements of the most sensitive species in the system. Modeling requirements may be much more stringent since the model will have to accurately predict dissolved oxygen levels on a much smaller time scale than a model developed to look at an average deficit over a 24 hour period. Unless the impacted dischargers propose to apply this provision of the standard and comply with all the requirements of 48-1-83 et seq. (1976, as amended), Code of Laws of South Carolina 1976, Pollution Control Act and the "Methodology for Determining a Permitting Dissolved Oxygen Deficit Allowance for Waters Not Meeting Numeric Standards Due to Natural Conditions," these alternate loadings can not be determined for inclusion in the TMDL. The Department cannot develop this information.

Issue: Inclusion of non-critical period limits in the TMDL.

21) Comment: Several commenters requested that seasonal, monthly or flow-based limits be included in the TMDL.

Response: The TMDL developed for the Ashley River is a low flow, high temperature, critical-condition TMDL. By definition, the TMDL wasteload allocations, which are based on critical conditions, should be protective of water quality at other times of the year.

Issue: Development of a new model.

22) Comment: Several commenters recommended that the BRANCH/BLTM model be abandoned in favor of a more appropriate model to be supported by additional data collection.

Response: The Department considers the BRANCH/BLTM model to be an acceptable tool for development of a TMDL for the Ashley River. The model has been developed by the U.S. Geological Survey and accepted by EPA Region 4 as an adequate tool for development of a TMDL for oxygen demanding substances in the Ashley River. Due to the significant impairment exhibited by the Ashley River during several months of the year, it would be inappropriate to delay implementation of measures to ensure compliance with applicable water quality standards.

The Department is not opposed to the development of a new model. In fact, a 3-dimensional model of the Cooper River and Charleston Harbor is currently in the planning stage. If this model is developed to include the Ashley River, then the new information would be considered.

Comments on the December 2000 draft TMDL for the Ashley River were received from:

Applied Technology & Management, Inc.
Charleston Metro Chamber of Commerce
Dorchester County Council
Lowcountry Manufacturing Council
Southern Environmental Law Center/S.C. Coastal Conservation League
S.C. Department of Natural Resources
Summerville Commission of Public Works

APPENDIX F

BCDCOG Allocation

Berkeley-Charleston-Dorchester
Council of Governments

July 25, 2003

Alton C. Boozer, Chief
Bureau of Water
SC DHEC
2600 Bull Street
Columbia, SC 29201

Dear Mr. Boozer:

Attached is the Ashley River TMDL allocation approved by the COG's Board of Directors at their meeting on July 14, 2003. You will note in reviewing the allocation that the Board of Director's has not yet approved an allocation for Carolina Water Services' King Grant Facility. This decision is based on the fact that the Kings Grant Facility remains classified as a temporary facility under the 208 Plan. The approved allocation plan holds their proposed allocation in reserve until such time as they can discuss with Dorchester County the elimination of their discharge and the diversion of their flow to the County's lower treatment facility.

Please call me if you have any questions or need further information.

Sincerely,

Ronald E. Mitchum
Executive Director

5290 Rivers Avenue Suite 400 North Charleston SC 29406 (843) 529-0400 Fax: (843) 529-0305
www.bcdcog.com

APPROVED ASHLEY RIVER TMDL ALLOCATION

Segment	Name	Flow (MGD)	DO (mg/l)	BOD (mg/l)	NH3 (mg/l)	UOD (lbs/d)	Total UOD (lbs/d)	Delta DO (mg/l)
1	CPW/City of Summerville	10	6.95	5	0.8	933	933	0.09
2	Middleton Inn	0.014	5	14	0.8	3	826	0.08
	Dorchester CPW/Lower Dorchester	4		14	0.8	823		

*Assumed F-Ratio = 1.5

Currently not allocated/held in reserve

1	CWS/Kings Grant on the Ashley	0.238	6.95	5	0.8	22	22	0.01

Berkeley-Charleston-Dorchester
Council of Governments

August 6, 2003

Alton C. Boozer, Chief
Bureau of Water
SC DHEC
2600 Bull Street
Columbia, SC 29201

Dear Alton:

As the department drafts the Ashley River TMDL, please insure that it includes the following information regarding Dorchester County's proposed expansion:

	BOD5	NH3	DO	UOD	Delta DO
8.0 mgd	7	.807	5	948	.08

The COG is currently in the process of amending the plan to increase the County's flow from 4.0 mgd to 8.0 mgd. It is anticipated that the process to amend the plan will be finalized at the Board's August 29, 2003 meeting. Since I have previously discussed the planned expansion with the Board and have received no negative comments, I expect the amendment to pass without objection. The inclusion of the 8.0 mgd limits in the draft TMDL should allow the department to move forward with the issuance of an 8.0 mgd permit as soon as the final TMDL is approved.

I appreciate your assistance in this matter; please call me if you have any questions.

Sincerely,

Ronald E. Mitchum
Executive Director

RECEIVED
AUG 7 2003
BUREAU OF WATER

5290 Rivers Avenue Suite 400 North Charleston SC 29406 (843) 529-0400 Fax: (843) 529-0305
www.bcdcog.com

APPENDIX G

Public Notices for the Revised TMDL

PUBLIC NOTICE

NOTICE OF AVAILABILITY OF PROPOSED TOTAL MAXIMUM DAILY LOAD FOR WATERS AND POLLUTANTS OF CONCERN IN THE STATE OF SOUTH CAROLINA

August 20, 2003

Section 303(d)(1)(C) of the Clean Water Act (CWA), 33 U.S.C. § 1313(d)(1)(C), and EPA's implementing regulation, 40 C.F.R. § 130.7(c)(1), require the establishment of total maximum daily loads (TMDLs) for waters identified in § 303(d)(1)(A) of the CWA. Each of these TMDLs is to be established at a level necessary to implement applicable water quality standards with seasonal variations and a margin of safety, accounting for lack of knowledge concerning the relationship between effluent limitations and water quality. The South Carolina Department of Health and Environmental Control (SCDHEC) has developed a proposed TMDL for the Ashley River in Charleston and Dorchester Counties. The pollutants of concern are oxygen-demanding substances: carbonaceous and nitrogenous biochemical oxygen demand. The TMDL indicates that a reduction in permitted loading of oxygen demanding substances to the Ashley River of approximately 32 to 36 percent is required to meet applicable water quality standards

Persons wishing to comment on the proposed TMDL or to offer new data regarding the proposed TMDL are invited to submit the same in writing no later than September 19, 2003 to the South Carolina Department of Health and Environmental Control, Bureau of Water, 2600 Bull Street, Columbia, South Carolina 29201, ATTENTION: Larry Turner. Mr. Turner's telephone number is: 803-898-4005. His E-Mail address is: turnerle@dhec.sc.gov

The proposed TMDL and the administrative record, including technical information, data, and analyses supporting the proposed TMDLs, may be reviewed and copied at 2600 Bull Street, Columbia, South Carolina between the hours of 8:00 a.m. and 4:30 p.m., Monday through Friday. Copies will be provided at a minimal cost per page. The draft TMDL documents will be available on the Internet at: http://www.scdhec.net/water/publicnote/html/eqpnwatertmdl.asp or http://www.scdhec.net/water/html/hottopics.html

After review and consideration of any comments and information provided during the comment period, the proposed TMDL will be sent to EPA for approval.

Please bring the foregoing to the attention of persons whom you believe will be interested in this matter.

NOTICE OF AVAILABILITY OF PROPOSED TMDL FOR WATERS AND POLLUTANTS OF CONCERN IN THE STATE OF SOUTH CAROLINA

The South Carolina Department of Health and Environmental Control (SCDHEC) has developed a proposed total maximum daily load (TMDL) for the Ashley River in Charleston and Dorchester Counties. This TMDL has been developed in accordance with Section 303(d) of the Clean Water Act and SCDHEC is now proposing to establish it as a final TMDL.

Persons wishing to offer comments regarding this proposed TMDL may submit comments in writing not later than September 19, 2003, to Larry Turner, SCDHEC, Bureau of Water, 2600 Bull Street, Columbia, SC 29201 or via E-mail at: turnerle@dhec.sc.gov. For more information please contact Mr. Turner at (803) 898-4005. A copy of the TMDL report will be available on the SCDHEC web page at: http://www.scdhec.net/water/publicnote/html/eqpnwatertmdl.asp or http://www.scdhec.net/water/html/hottopics.html

APPENDIX H

Responsiveness Summary to Public Comments
Revised Draft TMDL

SUMMARY OF PUBLIC COMMENTS AND DEPARTMENTAL RESPONSES
FOR DRAFT TOTAL MAXIMUM DAILY LOAD (TMDL) FOR THE ASHLEY RIVER
(Based on September 2003 Draft TMDL Notice)

The Department received comments on the proposed Ashley River TMDL from the following:

Commissioners of Public Works of the Town of Summerville
Dorchester County Public Works
MeadWestvaco Corporation
S.C. Dept. of Natural Resources
U.S. Environmental Protection Agency, Region 4

1. Comment: Two commenters stated they understood "that the final Ashley River TMDL will serve as a stand-alone management tool for the Ashley River as well as be integrated (as a boundary condition) into the ongoing 3-D model being developed for the Charleston Harbor and Cooper River by the BCD-COG".

Response: Since there has been no request that the TMDL be implemented in phases and the TMDL will be implemented as final limits in the permits, the department will not require participation by Dorchester County and Summerville CPW in the 3-D modeling effort. However, the decision as to what portion of the Ashley River is to be included in the 3-D model and how best to utilize new and existing water quality data and model outputs in the 3-D model will be made by the BCD-COG and their consultants.

2. Comment: Two commenters expressed concern that, while the TMDL will force existing dischargers to invest in tertiary treatment, it will not result in any measurable improvement in the quality of the river and that the river will still not meet applicable dissolved oxygen criteria due to natural conditions.

Response: The commenters are correct that during critical conditions the Ashley River will not meet applicable criteria for dissolved oxygen due to natural conditions; however, the Pollution Control Act (Title 48, Chapter 1) and the state water quality standards (R.61-68.D Antidegradation Rules) require that, where the dissolved oxygen standard is not attained due to natural conditions, a diminimus lowering of the dissolved oxygen concentration (defined as no more than 0.10 mg/l) be allowed due to point sources and other activities. Compliance with the criteria minimizes the impact from point source discharges on naturally low dissolved oxygen waters while allowing some discharge to these naturally stressed waters. The proposed TMDL complies with the requirements for discharges to naturally low dissolved oxygen waters.

3. Comment: Two commenters expressed concern that the plant upgrade required to meet the TMDL will take an extended period of time of as long as 5 years to design, install and place into service and therefore requested a "corresponding compliance schedule to achieve the substantial loading reductions called for in the TMDL."

Response: Compliance schedules will be addressed during the NPDES permitting process and incorporated into the permits as appropriate.

4. Comment: The South Carolina Department of Natural Resources offered no objection to the proposed TMDL "provided DHEC determines that the revised TMDL will be adequate to comply with the provision of R.61-68 that allows for a lowering of D.O. of no more than 0.10 mg/l."

Response: The proposed TMDL complies with applicable provisions of the Antidegradation requirements of R.61-68.

5. Comment: EPA commented that the TMDL does not provide any allocation for non-point source load reductions. The TMDL relies solely on control of point sources to meet the dissolved oxygen criteria under critical dry weather conditions. Similarly, on page 9 of the target identification section, the reports states, AThis TMDL focuses on compliance of point sources with the Tenth Rule. As such, non-point sources of pollution are considered in this analysis only as they impact boundary and background conditions of the modeling effort. EPA has reviewed the modeling approach and concurred that, given the current modeling for this system and the identified target for this analysis, a dry weather, critical condition TMDL, including only point sources, is appropriate.@ For the TMDL report, we recommend a more robust discussion of the non-point source assessment to explain why non-point source pollution is not a concern during dry weather. For example, the TMDL adequately addresses Sediment Oxygen Demand which accounts for the dry weather impacts of non-point source loads to the river.

Response: The critical conditions on which the wasteload allocations are based represent hot, dry periods during late summer. Freshwater inflow is limited to a nominal headwater flow of 5 cfs, which is considered to approach 7Q10, and WWTF effluent flow. Runoff would be absent during these periods, so direct inputs of anthropogenic non-point source BOD from land surfaces to the water column should be zero. Dissolved material introduced during runoff events should be flushed from the system along with the stormwater, which would prevent this material from impacting river DO levels during subsequent dry periods. Suspended material would tend to be transported downriver during high flow, but might also settle in some areas. Any impact from previous wet periods, as might result from benthic deposition and accumulation, is taken into account by the sediment oxygen demand (SOD), as noted in the comment, as well as benthic source terms for CBOD and NBOD that were determined during model calibration. Likewise, background, or natural, non-point sources should also be accounted for by the kinetic terms, as well as the inputs of CBOD and NBOD at the model boundaries. Since anthropogenic and background non-point sources are either absent during dry weather or incorporated through processes that are already included, non-point source pollution is not a concern in this analysis. As recommended, this discussion has been added to the TMDL report in the Target Identification section (2nd paragraph).

6. Comment: EPA commented that since this is a dry weather, critical condition TMDL, we are assuming that the load allocations are not being established for wet weather conditions. This is further supported by the fact that no allocations are provided to non-point sources. Please verify this assumption. Also, the State should clearly state the conditions under which the wasteload allocations apply in the TMDL section of the document on page 16.

Response: The assumption is correct; load allocations are not being established for wet weather conditions. The Critical Conditions Loading section (1st paragraph) has been revised to clarify that the wasteload allocations given in Tables 3a and 3b apply during both dry and wet weather conditions.

7. Comment: EPA commented "similarly, please clearly state the total maximum daily load that the State will request approval of by EPA. A table that clearly defines the TMDL, WLA, and LA for a given parameter provides EPA precise understanding of that which the Agency is reviewing for approval action. For the Ashley River TMDL, it is unclear whether the TMDL and WLAs are for UOD, CBOD5/BOD5, NH3-N[2], or all three. The WLAs can be provided as a lump sum or broken out for individual dischargers."

Response: The wasteload allocations are shown in Tables 3a (existing WWTF flows) and 3b (Dorchester County WWT expansion to 8 MGD). Both tables include wasteloads for CBOD5/BOD5 and NH3-N. The TMDL wasteload allocations are for CBOD5/BOD5 and NH3-N. As stated in the report, allowable UOD is dependent on the effluent mix of CBOD5/BOD5 and NH3-N. For this reason, individual wasteload allocations for CBOD5/BOD5 and NH3-N are required instead of the lumped UOD term. The inclusion of UOD in the tables is intended for information purposes only since it is commonly used to quantify oxygen demand. The UOD loads were of particular interest in this case for direct comparison to the draft Ashley River TMDL previously proposed in December 2000, which was based on UOD and is replaced by the current TMDL. However, the potential for some confusion is acknowledged, and clarifying footnotes have been added to the tables.

8. Comment: EPA commented that TMDL=s are to be established at levels necessary to implement the water quality standards applicable to the waterbody. According to page 9 of the TMDL report, AThe water quality target for this TMDL is a dissolved oxygen depression of no more than 0.10 mg/L, as a daily average, as authorized by Regulation 61-68, Section D.4 and the S.C. Pollution Control Act, Section 48-1-83.@ The TMDL document should state that the

controlling dissolved oxygen sag occurs in the Church Creek to Orangegrove Creek segment which is covered by a site-specific dissolved oxygen criteria of not less than 4.0/mg/l.

Response: The Waterbody Classifications and Dissolved Oxygen (DO) Criteria section (1st paragraph and Table 1) has been revised to clarify the locations where the different numeric standards apply. The Target Identification section (1st paragraph) has been revised to clarify the location of the controlling dissolved oxygen sag. Note the sag occurs in the Bacon Bridge to Church Creek segment, which carries a numeric standard of 5 mg/L (daily average) and 4 mg/L (minimum), not in the Church Creek to Orangegrove Creek segment identified in the comment.

9. Comment: Regarding the potential impact to endangered species, one commenter stated "Your comments should be limited to those aquatic or aquatic-dependent species that may be directly impacted by increased dissolved oxygen levels."

Response: The report section dealing with potential impacts to endangered species has been revised. Table 4 listing endangered species found in Berkeley, Charleston, and Dorchester Counties has been removed. The revised text refers to the shortnose sturgeon, *Acipenser brevirostrum*, as the species that would likely be most affected by any change in Ashley River DO levels.